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MONTANA DEPARTMENT
OF
NATURAL RESOURCES AND CONSERVATION

WATER RESOURCES DIVISION

TONGUE RIVER PROJECT

MODIFICATION FEASIBILITY STUDY

OCTOBER 1976

RICHARD SON AND ASSOCIATES
consulting engineers

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MONTANA DEPARTMENT

OF

NATURAL RESOURCES AND CONSERVATION

WATER RESOURCES DIVISION

TONGUE RIVER PROJECT

MODIFICATION FEASIBILITY STUDY

OCTOBER 1976

R.C. HARLAN AND ASSOCIATES

consulting engineers

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I SUMMARY

In southeastern Montana additional water is needed for irrigation and municipal water supply. There are extensive deposits of coal presently being developed in this area by the energy industry and additional water supplies are also needed to make optimum use of this natural energy resource. The Tongue River Project is intended to provide additional water for use by agriculture, municipalities and industry in southeastern Montana.

The spillway of the existing Tongue River Dam is inadequately sized to pass the probable maximum flood. Also, the spillway is in deteriorated condition and urgently needs replacement to provide for the safety of the reservoir. The potential failure of the Tongue River Dam would be a disaster to southeastern Montana. Not only heavy property loss would ensue but lives could be lost. The present dependable water supply would be gone for many years while the dam is reconstructed and the reservoir refilled. Loss of water supply would create great consequential financial loss to agriculture in the area.

This report presents alternative designs and cost estimates for enlarging the Tongue River Irrigation Reservoir including the spillway and raising the existing Tongue River Dam. The alternatives are compared with an updated cost estimate for the High Tongue River Dam previously proposed for construction downstream from the existing dam. Also included are preliminary designs (and cost estimates) for correcting the existing Tongue River Dam Outlet Works. We conclude that it is technically feasible to increase the storage in Tongue River Reservoir by raising the existing Tongue River Dam up to Elevation 3465 or by constructing the proposed High Tongue River Dam downstream.

Five alternatives for modifying the Tongue River Dam along with an updated cost estimate for the Stage 1 High Tongue River Dam are compared in the following table. The costs are based on beginning project design in 1977 and include engineering geotechnical investigation and surveys, construction of dam, spillway and outlet works, resident engineering during construction, and contingency allowance but do not include land, land rights, State of Montana administration, environmental investigation and reports, financing and interest costs, or escalation for delay in project start beyond 1977.

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Alternative	Comparative Cost	Total Firm Yield Water Supply Acre Feet Per Year	Increase in Firm Yield Water Supply Acre Feet Per Year
1. Modify Dam, Spillway and Outlet Works at Present Storage Elev. 3424.4	$ 28,754,000	42,000	-
2. Modify Dam, Spillway and Outlet Works to Storage Elev. 3438	32,130,000	67,500	25,500
3. Modify Dam, Spillway and Outlet Works to Storage Elev. 3465	32,669,000	100,000	58,000
4. Raise Modified Storage Elev. of 3424.4 to 3438	5,695,000*		
Raising Cost plus Alternative 1 Cost	34,449,000	67,500	25,500
5. Raise Modified Storage Elev. of 3438 to 3465	8,751,000**		
Raising Cost plus Alternative 2 Cost	40,881,000	100,000	58,000
6. Construct Stage I High Tongue River Dam downstream to Elev. 3438	63,501,000	100,000	58,000

* Additional amount to be added to Alternative 1 for Total Comparative Cost.

** Additional amount to be added to Alternative 2 for Total Comparative Cost.

These estimates do not include costs for land and land rights, State of Montana Administrative costs, Environmental Investigations and Reports, interest and costs of financing and escalation to beginning of project.

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II INTRODUCTION

This report presents feasibility level modification designs and cost estimates for the existing Tongue River Dam. The purpose of these designs and cost estimates is to provide the Montana Department of Natural Resources and Conservation with data to make decisions with regard to alternatives to the proposed High Tongue River Dam. Included are plans for replacing the existing inadequate spillway and modifying the dam to pass the probable maximum flood safely, along with correction of the outlet works. Also included are designs for incremental raising from the present reservoir storage level of 3424.4 to elevations of 3438 and 3465. Elevation 3438 allows for about 3.5 feet of freeboard before water is backed across the state line into Wyoming and is the same elevation as the spillway for the High Tongue River Dam. Elevation 3465 provides sufficient storage capacity to give the same firm yield as the High Tongue River Dam. Each of these raising plans includes the appropriate spillway and dam modification changes, improvements to the seepage control for the reservoir as considered appropriate on the basis of present information, and modification plans for the existing outlet works. Also included is an updated cost estimate for the proposed High Tongue River Dam, Stage 1, on the basis of the design presented in the Bechtel, Inc. Basic Design Report of 1969.

Tongue River water has been used for domestic and irrigation purposes since the late 1800's. In 1939, the Montana State Water Conservation Board constructed the Tongue River Dam which impounds the Tongue River Irrigation Reservoir for irrigation and other beneficial uses. The Tongue River Irrigation Reservoir is located on the Tongue River north of Decker, Montana, and is the major storage reservoir in the Tongue River Basin.

The location and vicinity maps for the Tongue River Project are shown on Figure 1. A reservoir map showing the extent of the water surface elevations and flood surcharge elevations for each of the alternatives is shown on Figure 2.

The scope of these studies is limited to the use of the design criteria and data contained in the reports prepared by Bechtel.

In 1967, the Montana Water Resources Board retained Bechtel, Incorporated to prepare a study on the feasibility of obtaining additional water supplies from the Tongue River in southeastern Montana. The results of these studies are presented in the "Basic Design Report for the Tongue River Project" by Bechtel, Incorporated, dated 1969. That report, which included a volume of supporting data, provided the basic information and criteria used in this modification feasibility study.

Another Bechtel study, designated "Water Allocation Study," presented information on the allocation of Tongue River water between the State of Wyoming and Montana under the Yellowstone River Compact. The "realistic" allocation of water developed by Bechtel in their studies was used as a basis for their determinations of firm yield of the Tongue River Basin. Due to the extent of the information, basic data and design criteria collected and developed in those reports, it is considered that they provide sufficient basis for these modification feasibility studies. Additional information has been provided by the Montana Water Resources Division staff. Summaries of data contained in the Bechtel reports on hydrology, geology and construction materials, have been included in the Appendix of this report to provide basic background information.

A detailed chronology of the Bechtel studies carried out in 1967-1969 is presented in the Appendix to this report for reference.

In 1975, the Montana legislature authorized the Montana Department of Natural Resources and conservation to study further alternatives of raising the storage elevation of the existing

Tongue River Dam. On September 8, 1976, the Department authorized R. C. Harlan and Associates to carry out the modification studies and cost estimates.

The following persons participated in these Modification Feasibility Studies:

Montana Department of Natural Resources
and Conservation
Water Resources Division

Orrin Ferris, Administrator
Richard Bondy, Chief Engineer
Robert Clark, Project Engineer

R. C. Harlan and Associates

Richard C. Harlan, Project Manager
Robert H. York, Project Engineer,
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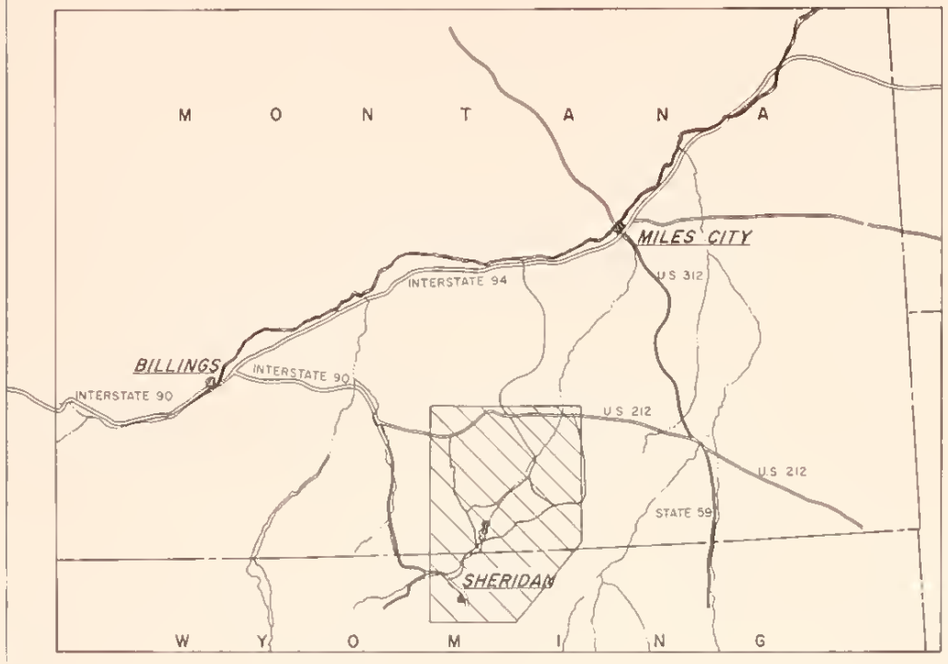
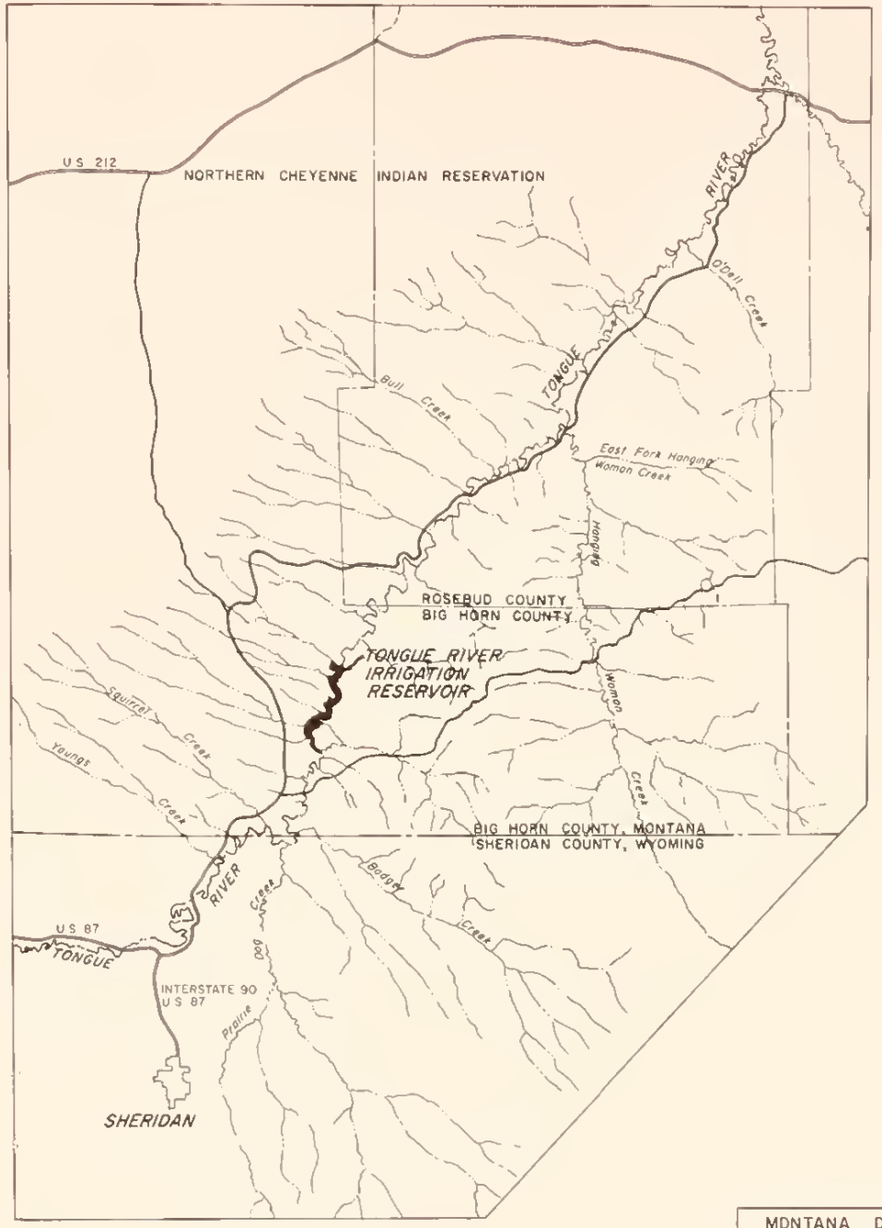
Richard G. Tait, Project Engineer,
Outlet Works Modifications
John N. Carver, Project Engineer,
High Tongue River Dam Estimate

Consultants

Herbert S. Riesbol, Hydrology and Hydraulics
Frank G. Bystrowski, Construction Costs
and Schedules



LOCATION MAP



VICINITY MAP TAKEN FROM AMS SHEET, HAROIN NL 13-7 SHERIDAN NL 13-10

VICINITY MAP

5 0 5 10 15

MILES

MONTANA DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION
WATER RESOURCES DIVISION

TONGUE RIVER PROJECT
MODIFICATION FEASIBILITY STUDY

LOCATION AND VICINITY MAPS

PROJ. NO.	169.1
DRAWN BY	RMS
APP'D BY	KH
DATE	11/29/76
SCALE	As Shown

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FIGURE 1

LEGEND

- Flood for storage elev 3465
- Storage elev 3465, and flood for storage elev 3438
- Storage elev 3438

MONTANA DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION
WATER RESOURCES DIVISION

TONGUE RIVER PROJECT
MODIFICATION FEASIBILITY STUDY

TONGUE RIVER IRRIGATION RESERVOIR
RESERVOIR MAP

PROJ. NO. 1169.1
DRAWN BY RMS
APP'D BY RCH
DATE 10/29/76
SCALE —

R. C. HARLAN AND ASSOCIATES

FIGURE
2

III TONGUE RIVER SYSTEM AND HISTORY OF WATER USE

Tongue River System

The headwaters of the Tongue River lie in the Big Horn Mountains of northern Wyoming. Flowing north and east through Wyoming into Montana, the Tongue finally joins the Yellowstone River at Miles City in eastern Montana. The Tongue River Basin is some 150 miles long and 40 miles wide, and includes some 5420 square miles of drainage area above the confluence with the Yellowstone.

Most of the water in the Tongue River Basin arises in the Big Horn Mountains in the tributaries North Tongue River, South Tongue River, Little Tongue River, Wolf Creek, Goose Creek, and Little Goose Creek. These tributaries flow from the mountains north and east across the high plains forming the main Tongue River north of Sheridan, Wyoming. Numerous ephemeral streams on the high plains join the main Tongue River from the north. In the plains south and east of Sheridan, Prairie Dog Creek forms and flows into the main Tongue River just before it crosses the Montana border.

In Montana, small ephemeral tributaries join the northward-flowing Tongue River from the west. Drainage from the east, however, is dominated by three major tributaries: Hanging Woman Creek, which joins the main river at Birney; Otter Creek, which joins at Ashland; and Pumpkin Creek, which flows into the Tongue River about 22 river miles above the confluence with the Yellowstone River at Miles City.

History of Water Use in the Tongue River System

While recent municipal use of water has been developed from the Tongue River, the predominant historical use has been for irrigation since the late 1800's.

In Wyoming,earliest irrigation water rights are before 1880. Extensive use of irrigation canals has developed in Wyoming leading to exchange of water between tributary basins.

Reservoirs for storage of irrigation water have been constructed, as well as numerous stock ponds. Water from Piney Creek, a tributary of the Powder River, has been imported into the Tongue River Basin by irrigation canals.

The predominant use of water from the main Tongue River in Montana has been for irrigation by direct diversion with rights dating from 1886. The Montana State Water Conservation Board constructed the Tongue River Irrigation Reservoir, the major storage reservoir in the basin, in 1939 for irrigation and other beneficial uses.

In the high plains country of southeastern Montana, additional irrigation is needed to permit agriculture to develop and to provide for increased domestic water supplies. Also, extensive deposits of coal are present at relatively shallow depth. Development of these coal resources by the energy industry will require substantial quantities of water for cooling and for process consumption.

IV WATER SUPPLY STUDIES AND FLOOD HYDROLOGY

Water Supply Studies

The water supply studies conducted by Bechtel have been detailed in the report "Water Allocation Study," 1968. The firm yield studies based on the "realistic allocation" of water are presented in the Bechtel "Basic Design Report," 1969. Excerpts from the Water Supply Studies section of that report are presented in the Appendix for reference.

The storage capacity and firm yield of the alternatives are as follows:

Alternative	Storage Capacity Acre Feet	Firm Yield Acre Feet Per Year
Existing Tongue River Dam Storage El. 3424.4	68,000	42,000
Raise Existing Tongue River Dam to Storage El. 3438	130,000	67,500
Raise Existing Tongue River Dam to Storage El. 3465	320,000	100,000
High Tongue River Dam Storage El. 3438	320,000	100,000

Realistic Allocation

Of great importance to this study is the utilization of the firm yield analysis developed by Bechtel on the basis of the "realistic" allocation of water. The allocation of water between Wyoming and Montana for the tributaries of the Yellowstone River is governed by the Yellowstone River Compact. The Compact provides in Article V that "supplemental" water allocation be provided for all water rights having a priority before January 1, 1950, which do not have sufficient supply to fully utilize the then existing rights. This provision means that the lands which do not have sufficient water supply to fully develop their potential use and which have water rights

for uses under the doctrine of appropriation having a priority before January 1, 1950, can obtain additional water supplies which would be exempt from allocation under the Yellowstone River Compact. This provision, therefore, creates a reservation of water for the future which could only be claimed for actual use on lands and for uses having a priority before 1950. In order for such uses to be realized, the existing canal and lateral capacities would have to be enlarged to carry the water for which surplus rights exist. Additional storage on many tributaries would have to be provided to retain flood run-off in excess of existing direct diversion and storage rights for later release of supplemental water.

The Bechtel Allocation Study carefully evaluated the whole amount of possible future uses of surplus and supplemental water to augment the pre-1950 rights in the "strict" allocation. The reservation of these water uses for the future greatly reduced the amount of unused and unappropriated water available for allocation to both Wyoming and Montana. The magnitude of this reduction is judged to be unrealistic. The pre-1950 rights are almost entirely for agricultural or domestic uses. Therefore, the conversion of such rights to other purposes, such as industrial, appears to be outside the provisions of the Compact. The present agricultural and domestic uses would not justify the substantial expense necessary to improve the conveyance and storage systems to the extent necessary to make the use of these surplus and supplemental waters possible.

Therefore, in recognition of the foregoing limitations on development of conveyance and storage systems, Bechtel developed the "realistic" allocation. The "realistic" allocation provides a more reasonable reservation of water for surplus and supplemental rights, thereby leaving more water available for allocation between Wyoming and Montana. With a more reasonable assessment of the waters reserved for supplementing pre-1950 water rights, more water is available for new uses by agriculture, municipalities,

and industry within the Tongue River Basin.

It is also important to note that the existing storage rights held by Montana at the Tongue River Reservoir is considered a pre-1950 right regardless of the use made of the water. (This is not a surplus or supplemental right, but a fully appropriated pre-1950 right).

The Bechtel Water Supply Study also made recognition of water rights for the Northern Cheyenne Indian Reservation. In addition to 30 cfs of decreed rights for the reservation lands, Bechtel reserved an additional 60 cfs as an allowance for future water development on the reservation.

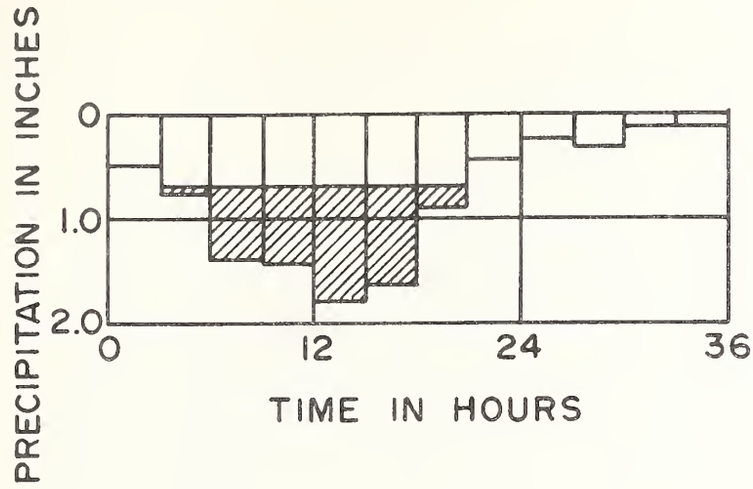
We conclude on the basis of our review of these considerations that the Bechtel conclusion remains valid and that the "realistic allocation" remains an appropriate basis for water supply planning in both states.

The Bechtel Basic Design Report describes the calculation of storable inflow, firm yield and storage, provision for seepage and evaporation losses at various reservoir storage elevations (for the High Tongue River Dam), and allowances for siltation. The results of the studies of reservoir storage and elevation are presented on Bechtel Drawing 6694-111-002, presented here for reference.

Flood Hydrology

The design flood developed by Bechtel for the Tongue River Dam Project has been used in these modification feasibility studies. The inflow hydrograph of that storm is presented on Bechtel Figure IV-1 included herein for reference.

The design flood was based on the very large storm that occurred along the eastern flanks of the Rocky Mountains in northwestern Montana on June 7 and 8, 1964.



Combined Losses

Excess Precipitation

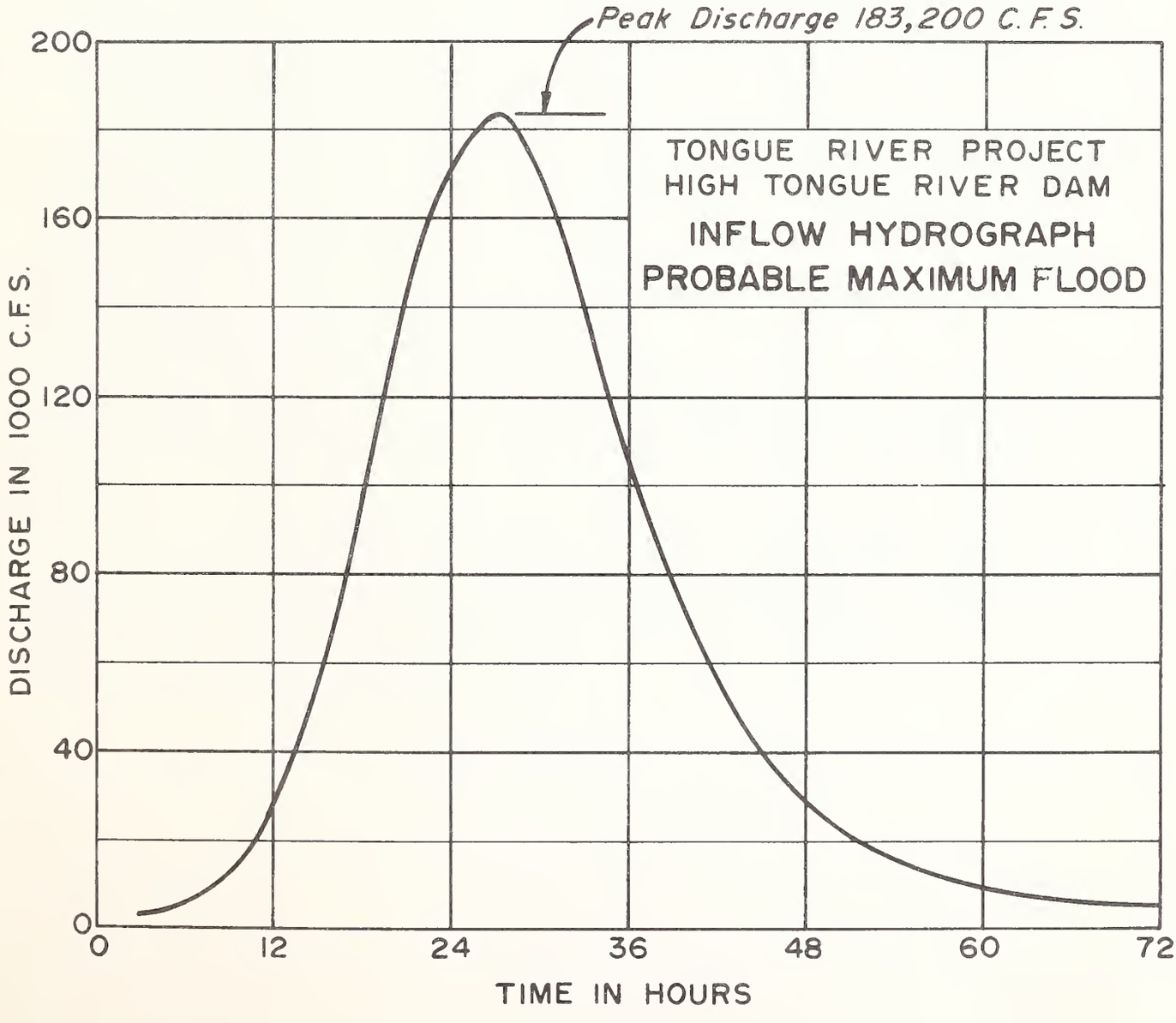


FIGURE IV - 1

V GEOLOGY

The geology of the Tongue River Project area is relatively simple. The local formation is the Tongue River member of the Fort Unit Formation consisting of relatively flat lying siltstones, sandstones, claystones and coal deposits. A detailed description of the geology excerpted from the Bechtel Basic Design Report is included in the Appendix.

An interesting feature of the local geology is the occurrence of baked rock, locally called clinker or scoria. Where coal beds have been exposed by erosion in hillsides or cliffs, they have burned causing the adjacent sedimentary rocks to bake. The baked rocks are characteristically reddish. Where the burned coal has left voids, collapse breccia has resulted. The broken rock is highly pervious yet strong and resistant to erosion.

Where overburden was thin, the rocks baked over large surface areas. Where overburden was thick, the coal burned only at outcrops but still several hundred feet into the hill.

The geologic conditions at the existing Tongue River Damsite are suitable for raising the water storage level of the existing Tongue River Reservoir. The foundations are relatively strong except where lenses of clay shale are present. Substantial attention must be paid to providing seepage control for the raised water level, particularly where "baked rock" is present.

The new spillway has been located on the basis of some judgment as to the extent of the highly pervious "baked rock." Substantial subsurface exploration will be required to properly locate the new spillway.

VI CONSTRUCTION MATERIALS

Ample earth construction materials are available for raising the existing Tongue River Dam. Data on construction materials excerpted from the Bechtel Design Report are presented in the Appendix. The spillway excavation will generate large quantities of random and impervious fill for main embankment construction and clinker, "baked rock," for slope and drawdown protection. Nearby terraces may produce suitable sand and gravel by processing for filter and drain zones, and perhaps even for concrete. Additional borrow material is available for fill construction from the Leaf Rock Creek area.

Our investigations indicate that concrete aggregates and filter and drain materials are available from commercial sources near Decker. Our cost estimates are based on the uses of these sources.

VII DAM EMBANKMENT

On the basis of the geologic and subsurface boring data available, we conclude that it is technically feasible to design and construct a raised dam in the present position of the existing Tongue River Dam. The present location of the Tongue River Dam is adequate for a reservoir with permanent storage elevation up to 3465.

The raising of the High Tongue River Dam embankment has been coordinated with the layout and design of the replacement spillway. The most economical combination of spillway crest length and dam height should be determined by thorough analysis when the storage elevation has been selected. The designs presented here are based on judgment to strike an economical balance between spillway costs and dam embankment raising costs.

Embankments have been designed for three crest elevations. The 3554 crest elevation is coordinated with the present storage level elevation of 3424.4. Because considerable material is generated by the excavation for the proposed spillway, it is more economical to utilize this material for construction of a raised embankment than to make the spillway crest length 600 feet to pass the probable maximum flood with the dam at its present crest elevation. The same consideration pertains to the storage elevations of 3438 and 3465. The 3438 and 3465 storage elevations require dam crest elevations of 3464 and 3489 to provide for two feet of freeboard above the flood pool for the maximum probable flood. For the first stage of construction to 3438 for further raising to 3465, the dam crest would be 3466. In order to eliminate problems of relocation of the access road over the spillway, the spillway crest walls would be built to the final stage height so that the bridge and roads would not have to be reconstructed.

Seepage Control

An important aspect of raising the Tongue River Dam storage elevation will be the provision of adequate seepage control. The present designs include several features for improving the seepage control of the present facilities. These are of critical importance, not only to increase safety over that of the present structure, but also to accommodate the higher seepage pressures which will be imposed by the raised water surface. The present hydraulic height of the dam is about 75 feet from the maximum storage elevation to the old streambed downstream of the existing dam. The new height will be approximately 115 feet (at Elev. 3465).

Features of seepage control included in the proposed designs are:

1. Extension of the existing impervious zone upward and downstream to provide for a substantial impervious core in the raised dam.

2. Construction of a chimney drain downstream of the impervious core section to provide for positive relief of seepage pressures within the embankment.

3. Construction of an extensive impervious blanket on the right abutment into the draw upstream of the dam to provide for improved seepage control and a longer seepage path around the right abutment of the dam. The effectiveness of this blanket on the right abutment will be somewhat limited by the inability to dewater the reservoir to extend the blanket to the bottom of the dam.

4. Extension of the cutoff trench on the left abutment and across the existing spillway. At this location a deep zone of baked rock is present which requires a positive seepage cutoff. When the new spillway is constructed, the old spillway can be partially demolished, the baked rock excavated and a positive impervious fill cutoff constructed to connect to the core and cutoff of the existing dam. This cutoff extension is an essential part of improving the seepage control on the left abutment in the vicinity of the existing spillway and outlet works.

5. Construction of a toe drain to relieve seepage pressures under the downstream shell of the dam. The existing cutoff is probably adequate for the present water surface elevation but should not be expected to be adequately effective for the increased reservoir head. Therefore, positive measures

to improve the downstream seepage control in the alluvial deposits under the downstream shell must be included in these preliminary designs. During design for the selected alternative facilities, detailed explorations must be made of this area downstream and it may be possible to determine that such massive seepage control measures are not needed. Alternatively, relief wells could be provided. If the toe drain were not installed and peizometers later indicated higher than anticipated seepage pressures within the river bed alluvium, then deep relief wells could be installed. However, the design of adequate seepage control requires further exploration and detailed analysis and we believe that it would be better for the comparative cost estimates to include a deep toe drain trench such as that planned for the High Tongue River Dam.

The embankment as designed has been planned to provide for adequate stability against the low foundation shear strengths, to develop seepage control within the embankment considering the condition of the existing dam and to provide for improved seepage control on the abutments. It has been designed to utilize materials generated from the spillway excavation for both random and impervious fill. We consider that it may be possible to develop sources of sand and gravel from the terrace deposits along the river for use in processing into filter and drain zones for the embankment; however, we have based the cost estimates on obtaining the filter and drain materials from commercial sources near Decker.

The dam has been planned with a relatively flat downstream slope for the raised condition and includes large berms. The purpose of this design is to compensate for relatively low shear strength foundation materials. The dam is planned to use the material excavated from the spillway for use as impervious fill and as random fill.

The use of the "baked rock" as slope protection both upstream and downstream is notable. While modern dam practice would indicate that the use of hard rock riprap would be the proper method of slope protection, it is noted that the existing Tongue River Dam has survived some 37 years utilizing the "broken baked rock" material in a very wide zone for upstream slope protection. Observations of wave action on the slope indicate

that the small waves generated in the short effective fetch of the reservoir, less than one mile, only create small waves which are dissipated within the baked rock zone.

The designs shown on the drawings of this report are largely based on judgment and cursory stability analysis using infinite slope procedures. Detailed stability analysis can only be carried out when an alternative plan has been selected and additional field information is obtained.

Basic data for preliminary design of the embankments is contained in the Bechtel Basic Design Report Supporting Data. Parameters used for this study are:

Type of Material	Strength Parameter Friction Angle Degrees	Unit Weight Moist lbs/cu.ft.	Unit Weight Saturated lbs/cu.ft.
Existing Dam Embankment	32	125	135
Clay Shale Foundation Layers	20	-	115
Alluvial Streambed Foundation	30	-	130
Shell and Core Material from Leaf Rock Creek and Spillway Excavation	32.5	120	130
Filter and Drain	32.5	120	130
"Baked Rock"	33.5	77	115

Extensive instrumentation will be required to monitor the seepage performance of the raised dam and its foundations. A detailed layout of instrumentation has not been made but a substantial cost allowance has been included.

VIII SPILLWAY

The key decision with regard to the Tongue River Dam modifications is whether the existing spillway should be repaired and modified to safely pass the probable maximum flood or replaced with a new spillway. The results of our studies indicate that on the basis of safety and economy, a new spillway should be constructed, west of the existing spillway. The factors upon which our conclusion is based are:

1. The ogee crest length needed for a spillway at the present storage elevation with the dam crest at its present elevation would be approximately 600 feet to safely pass the probable maximum flood. The present spillway crest, which is 350' long, requires widening.

2. The existing spillway structure is known to be unsound on the basis of offsets in the slab joints, deterioration of concrete and seepage emerging through the slab. It is also known to be partly, if not largely, founded on loose and collapsing "baked rock."

3. The present seepage control across the upstream approach of the spillway is inadequate for a raised reservoir storage level. Developing adequate seepage control would be difficult at the present location.

4. Since the spillway must be compatible with future water storage elevation increases, the spillway would have to be essentially rebuilt.

5. Either the outlet works or the spillway discharge must be separated from its present location so that access and maintenance of one of these facilities is possible while the other is functioning. At present, they both discharge at the same point and there is no access to the outlet works tunnel if the spillway is operating and there is no access to the downstream end of the spillway while the outlet works is functioning. Therefore,the discharge section of one of these facilities should be relocated.

6. The embankment material generated from the spillway excavation for a relocated spillway can be used to raise the dam embankment and thereby reduce the cost of the new spillway by making the ogee crest shorter in length. By relocating the spillway it is possible to found it on a location not underlain by baked rock and therefore eliminate many of the seepage control problems that have plagued the left abutment of the dam and the spillway.

On the basis of the geologic mapping and subsurface exploration available, we have selected a new spillway location that we judge is likely to be relatively free of baked rock. However, subsurface exploration will be needed to determine whether or not the tentatively selected location is in fact the most appropriate.

The spillway flood routings have been made using the reservoir storage capacity and probable maximum flood data contained in the Bechtel Basic Design Report. A spillway crest length of 250 feet was selected as giving a reasonable balance between ogee crest length against the increased height of dam. When the storage elevation for modification of the dam has been selected, a detailed economic analysis of dam height versus spillway crest length should be made. For dam raising projects it is generally found that narrower spillways and higher dams are more economical. In this case, however, if the spillway is narrowed, the discharge velocity from the stilling basin would increase somewhat, which may not be acceptable.

The replacement spillways for the existing Tongue River Dam are wider than the spillway for the proposed High Tongue River Dam. Because of the greater area of the High Tongue River Reservoir, the flood attenuation is greater than at the existing Tongue River Reservoir and the outflow discharge is correspondingly smaller. In order to maintain comparable discharge velocities from the stilling basins, the spillway at the existing Tongue River Dam is proposed to be wider.

The results of the flood routing studies for the various spillway alternatives at the existing dam are summarized in the following Table:

SUMMARY OF FLOOD ROUTING

Spillway Crest Length is 250 Feet for All Cases

Spillway Crest Elev.	Average Discharge Coefficient C	Peak Discharge (cfs)	Flow Depth Peak Discharge (ft)	Max. WS Elev.	Freeboard (ft)	Dam Crest Elev.
3424.4	3.4*	120,000	26.9	3451.3	2.7	3454
3438	3.9**	112,000	23.5	3461.5	2.5	3464
3438	3.4*	107,000	25.0	3463.0	3.0	3466
3465	3.9**	94,000	21.0	3486.2	2.8	3489

The spillway crest structure is designed to facilitate raising. The bridge would be installed at the ultimate height. The ogee weir for the first stage would be a low profile with adequate foundation for the raised weir. The chute is designed as a straight section with minimum slope to reduce excavation. The stilling basin is sized as a U.S. Bureau of Reclamation Type III basin with armored blocks. Exit velocities are in the range of eight to nine feet per second. Relief wells would be provided to prevent basin flotation.

* Average discharge coefficient for the low profile, less hydraulically efficient spillway crest designed for subsequent raising.

** Average discharge coefficient for high profile ogee crest.

IX OUTLET WORKS

Description, Operation and Condition of Existing Outlet Works

The general arrangement of the outlet works is illustrated on Figure 15. The existing facilities consist of an intake structure and a reinforced concrete lined tunnel with a double gated control section. The intake facility is a box-type structure with bars for screening debris. The tunnel is horse-shoe-shaped and 16' in equivalent diameter. Flow is controlled by two 6' x 12' slidegates located at the approximate upstream one-third of the tunnel. Flow is discharged through the spillway slab, just above the flip section of the spillway chute. On the basis of 36 years performance, this method of "energy dissipation" has been adequate and no need for a special energy dissipation structure is apparent.

In recent years, relatively high flows have been passed through the outlet works to maintain low reservoir levels so that spilling is minimized. The higher than previous discharges coincide with recent erosion of concrete and undermining of steel plate liners at the control section. Repairs have been necessary and in the fall of 1975 the concrete was patched and steel liner plates were replaced.

Our preliminary engineering analysis indicates that the probable cause of the distress is cavitation resulting from inadequate venting at the control section. Poor concrete quality might be a contributing factor since cracked and deteriorated concrete is visible in the tunnel and spillway. Possibly, an alkalai-aggregate reaction could be occurring.

Our studies indicate that for proper venting to avoid cavitation, a pipe approximately 24 inches in diameter should be provided for air supply. Moreover, for effective air introduction, the distribution of incoming air should be made over as much of the control section as possible.

Criteria

Hydraulic criteria used in our modification studies were as follows:

Normal operation release:

Industrial use	100 cfs
Prior adjudicated rights and allowance for reserve Indian lands	342 cfs
Existing agricultural contracts	133 cfs
Total	575 cfs

Winter release (for ice control) 75 cfs

Maximum release: 2250 cfs

The maximum release for emergency reservoir lowering was determined as that required to release one-third of the reservoir capacity (320,000 acre feet for storage elevation 3465) in 30 days. Reservoir inflow was assumed at 500 cfs.

At present, the tunnel is not accessible when spilling occurs. To facilitate tunnel maintenance, an additional design requirement is that the tunnel should be accessible during low volume spillway operation.

Alternatives

Our studies indicate that there are two principal schemes that will satisfactorily provide controlled releases for each of the dam alternatives. Both schemes utilize the existing outlet facilities and require a) corrections to the hydraulic design of the control section, and b) extension of the vertical outlet gate machinery shaft.

Briefly, Scheme 1 would be to maintain flow control by use of the existing slide gates. Scheme 2 would change the hydraulic design from flow control in the tunnel to flow control at the portal by means of a) an 11-foot diameter steel conduit installed between the existing and new control sections, and b) two fixed-cone dispersion valves downstream from the portal. Major features of both schemes are summarized on the following page.

MAJOR FEATURES OF OUTLET WORKS MODIFICATIONS

Scheme 1 (See Figure 15)

1. Provide additional ventilation at control section by means of 24" diameter steel pipe supported at tunnel crown.

2. Extend liner plates as precaution against cavitation.

3. Extend vertical outlet control structure equal to dam raise. For higher raise to dam crest 3489, a bridge to the tower will be needed.

4. Construct concrete weir to permit tunnel inspection and maintenance.

5. For higher raise, extend outlet terminous by means of reinforced concrete box structure.

Scheme 2 (Scheme 2 is not illustrated)

1. Same as 1 - 3 for Scheme 1.

2. Install transition section and 11' diameter x 3/8" wall thickness steel conduit between existing control section and new downstream control valve structure.

3. Construct concrete control valve house and provide two 72" fixed-cone dispersion valves on terrace approximately 20' above existing river bed.

4. Provide concrete wall to exclude backwater from tunnel.

5. Excavate new discharge channel to conduct releases from control valve structure to existing river channel.

6. Provide 48" outlet tee with blind flange as tie-in point for possible future pipeline.

A detailed cost estimate for Scheme 2 has not been prepared because its cost is at least five times greater than Scheme 1.

With Scheme 1, access to the tunnel would be provided in the following manner: a) a concrete weir "cofferdam" would be constructed approximately 50' downstream from the point of discharge. Weir height would be sufficient so that backwater from low quantity spills would not overtop the weir (we judge that a height of 4' to 8' would be adequate). When access

is desired, water impounded by the weir would be pumped out. With Scheme 2, the tunnel would be accessible at all times because discharges would bypass the portal and be made at an elevation higher than maximum backwater elevation. Portal submergence would be prevented by a concrete wall.

Recommended Plan and Discussion

On the basis of concept level cost estimates, Scheme 1 is more economical and is our recommended plan. While this scheme makes tunnel accessibility difficult in that the water impounded between the cofferdam (weir) and the tunnel portal must be pumped prior to inspection, the pumping costs and the inconvenience are small in comparison to the savings that Scheme 1 offers.

In this preliminary evaluation many assumptions have been necessary as a result of the limited scope of this study. A major assumption is that the tunnel is structurally adequate for future use. This assumption depends largely on the concrete quality. While there is some visual evidence of poor concrete quality, the Board staff reports that one sample of tunnel concrete has been cored and test results indicate a compressive strength of 5000 psi. This strength indicates satisfactory concrete, however, a more extensive test program should be conducted to properly evaluate concrete quality.

Another key assumption is that the present gates would be structurally adequate against hydrostatic pressures from higher reservoir levels. A detailed stress analysis would have to be made to confirm that point, although we judge that the gates are adequate.

X COST ESTIMATES

Comparative feasibility cost estimates have been prepared for the various alternatives. A breakdown of quantities and costs is presented on the table following. The basis for the costs of raising the existing dam is a three-year construction period following one year for exploration, design and preparation of plans and specifications. The basis for the updated cost estimate for constructing the new High Tongue River Dam is a four-year construction period following one year of exploration, design and preparation of plans and specifications.

A contingency allowance of 25% is recommended for the raising alternatives and 15% for the High Tongue River Dam. This disparity stems from our experience which indicates there are proportionately more unknowns at the feasibility stage for raising an existing dam than for new construction.

The cost estimates were prepared in the following manner. Since the design for the High Tongue River Dam, Alternative 6, was well developed, the quantity estimates were begun for that alternative immediately upon authorization for this study. The quantity estimates led directly into the High Tongue River Dam cost estimates while the feasibility modification design data were being developed for the existing Tongue River Dam.

Detailed construction plant, equipment and labor elements were developed and priced. Unit direct construction costs of significant items of work for the High Tongue River Dam were developed and overhead, profit and bond costs added. Using the unit costs developed in detail for the High Tongue River Dam, these units were applied to the quantities developed for the existing Tongue River Dam plans, with appropriate factors used to allow for the disparity in sizes of the projects. Overhead, profit and bond costs were then factored into the key item units and a Comparative Total Project Construction Estimate developed. Allowances for contingencies were then added.

Engineering budgets were developed on the basis of the Comparative Construction Estimates. Fee curves developed by the American Society of Civil Engineers were used. Curve B, for projects of average complexity, was used for High Tongue River Dam. It was assumed that 30% of the fee was preliminary engineering which has already been completed. Curve A, for projects of above average complexity, was used for the alternative modifications to the existing Tongue River Dam. It was considered that only 20% of the basic engineering has been completed in the preliminary work. For each project the basic engineering fee as estimated above was divided two-thirds for design, plans and specifications, and one-third for engineering during construction. A detailed man-month estimate was made for Management of Construction for High Tongue River Dam, based on four, 7 month construction seasons. The percentage of Management of Construction Cost to Comparative Total Project Construction Estimate was developed and used to determine Mangement of Construction estimates for the other alternatives. Estimates for geotechnical exploration and surveys were also developed for each alternative.

Costs not included in the estimates are: land and land rights, State of Montana Administration, environmental investigations and reports, financing and interest and escalation for delay of project beyond 1977. It appears that a delay of some two years will result from making the necessary environmental studies. For each year that the project is delayed beyond 1977, the Total Project Estimate should be multiplied by a factor of 1.07 to 1.10 for escalation-inflation.

	I Modify Existing Structures to Storage El. 3424.4	II Modify Existing Reservoir to Storage El. 3438	III Modify Existing Reservoir to Storage El. 3465	IV Raise Existing Reservoir from Modified 3424.4 to 3438	V Raise Existing Reservoir from Modified 3438 to 3465	VI High Tongue River Dam Storage El. 3438
Reservoir Area, Storage - Acres	3,300	5,000	8,400	5,000	8,400	7,700
Reservoir Area, Flood Pool - Acres	6,700	8,100	10,400	8,000	10,400	11,200
Reservoir Capacity - Acre Feet	68,000	130,000	320,000	130,000	320,000	320,000
Firm Yield - Acre Feet Per Year	42,000	67,500	100,000	67,500	100,000	100,000

	Quantity	Estimated Cost Dollars	Quantity	Estimated Cost Dollars	Quantity	Estimated Cost Dollars	Quantity	Estimated Cost Dollars	Quantity	Estimated Cost Dollars	Quantity	Estimated Cost Dollars
DAM EMBANKMENT												
Excavation - Dam Foundation, Drains, Cutoff, Outlet Works	962,100 cu.yds.	$ 3,384,000	1,159,100 cu.yds.	$ 3,787,000	1,159,100 cu.yds.	$ 3,769,000	125,000 cu.yds.	$ 321,000	131,000 cu.yds.	$ 331,000	2,880,000 cu.yds.	$ 8,606,000
Embankment Fill - incl. blankets	1,541,100 cu.yds.	2,754,000	2,056,100 cu.yds.	3,739,000	3,376,100 cu.yds.	4,924,000	441,000 cu.yds	1,067,000	1,123,000 cu.yds.	2,544,000	11,000,600 cu.yds.	17,307,000
Drilling and Grouting	Lump Sum	264,000	Lump Sum	264,000	Lump Sum	264,000	Lump Sum	7,000	Lump Sum	13,000	80,500 feet	1,632,000
Instrumentation	Lump Sum	120,000	Lump Sum	140,000	Lump Sum	170,000	Lump Sum	20,000	Lump Sum	30,000	Lump Sum	211,000
Subtotal Dam Embankment		$ 6,522,000		$ 7,930,000		$ 9,127,000		$ 1,415,000		$ 2,918,000		$ 27,756,000
SPILLWAY												
Excavation and Backfill	1,556,400 cu.yds.	$ 3,443,000	1,374,400 cu.yds.	$ 3,060,000	1,177,400 cu.yds.	$ 2,645,000	4,000 cu.yds.	$ 16,000	5,000 cu.yds.	$ 19,000	3,096,500 cu.yds.	$ 6,818,000
Concrete, inc. cement re-steel waterstops and included items	43,600 cu.yds.	8,705,000	45,900 cu.yds.	9,146,000	39,300 cu.yds.	7,843,000	4,800 cu.yds.	1,169,000	10,900 cu.yds.	2,530,000	56,400 cu.yds.	10,521,000
Drains	7,613 feet	244,000	7,613 feet	244,000	7,613 feet	244,000	-0- feet	-0-	-0- feet	-0-	10,150 feet	668,000
Bridge	Lump Sum	486,000	Lump Sum	486,000	Lump Sum	486,000	Lump Sum	-0-	Lump Sum	-0-	Lump Sum	394,000
Subtotal Spillway		$ 12,878,000		$ 12,936,000		$ 11,281,000		$ 1,185,000		$ 2,549,000		$ 18,401,000
OUTLET WORKS												
Concrete, incl. cement, re-steel waterstops and included items	50 cu.yds.	$ 16,000	136 cu.yds.	$ 140,000	1,250 cu.yds.	$ 738,000	Lump Sum	$ 116,000	1,137 cu.yds.	$ 509,000	14,700 cu.yds.	$ 2,643,000
Steel Conduit		-0-		-0-		-0-		-0-		-0-	932,000 lbs.	1,115,000
Outlet Valves, Operating System		-0-		-0-		-0-		-0-		-0-		
Air Inlet pipe, manifold and bridge	Lump Sum	91,000	Lump Sum	91,000	Lump Sum	160,000	Lump Sum	-0-	Lump Sum	65,000		
Bypass Pumping	Lump Sum	278,000	Lump Sum	278,000	Lump Sum	278,000	Lump Sum	-0-	Lump Sum	-0-	Lump Sum	646,000
Subtotal Outlet Works		$ 385,000		$ 509,000		$ 1,176,000		$ 116,000		$ 574,000		$ 4,404,000
ROADS AND SITE WORK												
Road Relocation	-0- miles	-0-	5 miles	$ 1,485,000	6 miles	$ 1,777,000	5 miles	$ 1,393,000	1 mile	$ 278,000	-0- miles	$ -0-
Road Improvement	10 miles	$ 1,189,000	5 miles	594,000	4 miles	474,000	0 miles	-0-	0 miles	-0-	1 mile	212,000
Site Work	Lump Sum	19,000	Lump Sum	23,000	Lump Sum	35,000	Lump Sum	10,000	Lump Sum	20,000	Lump Sum	47,000
Subtotal Roads and Site Work		$ 1,208,000		$ 2,102,000		$ 2,286,000		$ 1,403,000		$ 298,000		$ 259,000
COMPARATIVE TOTAL PROJECT CONSTRUCTION ESTIMATE		$ 20,993,000		$ 23,477,000		$ 23,870,000		$ 4,119,000		$ 6,339,000		$ 50,820,000
ALLOWANCE FOR CONTINGENCIES		$ 5,248,000		$ 5,869,000		$ 5,968,000		$ 1,023,000		$ 1,585,000		$ 7,623,000
ENGINEERING												
Geotechnical Investigation and Surveying		$ 195,000		$ 195,000		$ 195,000		$ 25,000		$ 25,000		$ 130,000
Design Engineering, Plans and Specifications		659,000		736,000		750,000		177,000		266,000		1,118,000
Engineering during Construction, Management of Construction		1,659,000		1,853,000		1,886,000		351,000		536,000		3,810,000
Subtotal Engineering		$ 2,513,000		$ 2,784,000		$ 2,831,000		$ 553,000		$ 827,000		$ 5,058,000
COMPARATIVE TOTAL PROJECT ESTIMATE		$ 28,754,000		$ 32,130,000		$ 32,669,000		$ 5,695,000		$ 8,751,000		$ 63,501,000

Additional items not included which must be added to this estimate include land and land rights, State of Montana Administrative costs, Environmental Investigations and Reports, interest and costs of financing and escalation to beginning of project.

XI RECOMMENDATIONS FOR FURTHER STUDY

As previously noted, this study is limited in scope to provide only sufficient data for comparison among alternatives. The cost estimates in this report are considered to be comparable and adequate for selection of the proper alternative.

On the basis of the data presented herein, it appears that optimization of the project features for greatest benefits-to-cost ratio may be achieved by yet another alternative. A more economical dam and spillway combination could probably be achieved to provide for more cost-effective raising in a second stage. That combination would consist of a first stage with a spillway crest elevation 3438 (high overflow profile) provided with piers, facilities and embedded plates for later installation of tainter gates and hoists. The gates would be 28 feet high (27 feet to store to 3465 with one foot of freeboard). Dam crest would be about 3471. Some reduction in reliability would have to be accepted and even an emergency spillway would possibly have to be considered. For the raising, no earth or concrete work would be required, only installation of the gates.

Additional study is recommended on the following items before a definite project configuration and financing estimate is developed:

1. Additional alternative with spillway gates for raising.

2. Installation of a small hydroelectric plant to provide sale of electrical power to offset project costs.

3. Accurate firm yield study based on specific project configuration.

4. Estimate evaporation and seepage losses from the enlarged reservoir.

5. Determine current active storage and updated siltation rates for reservoir.

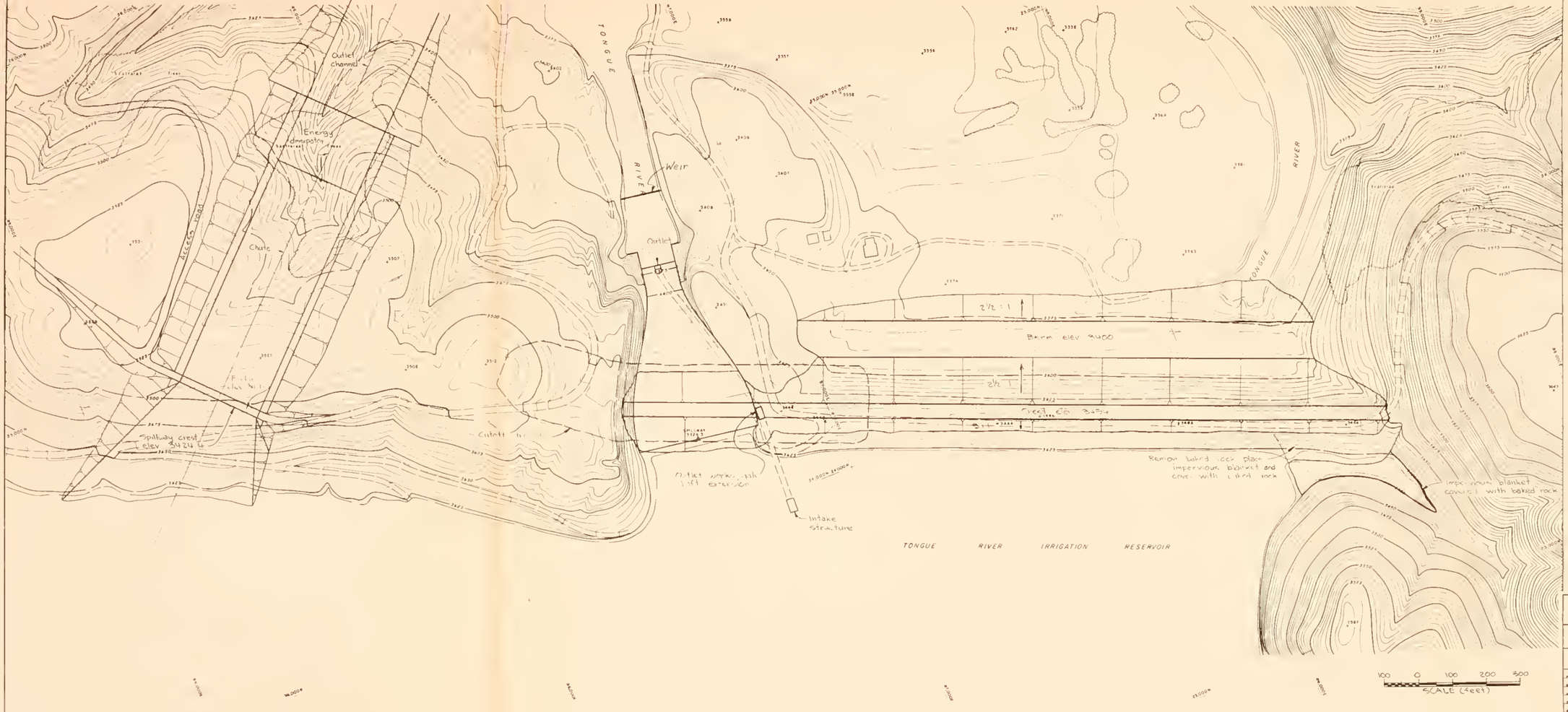
6. Further observation and study of outlet works performance and possible modifications.

7. Detailed subsurface geotechnical explorations and testing.

8. Specific construction materials investigation including concrete aggregates and embankment filter and drain materials.

9. Review storm hydrology.

10. Perform study of filling rates as related to financing and scheduling analysis.



NOTE
GRID IS BASED ON LOCAL COORDINATE SYSTEM
FIELD SURVEY CONTROL BY R W TOWILL CORP
ELEVATIONS ARE BASED ON MEAN SEA LEVEL DATUM 1929 ADJ

NOTE
IN OPEN UNOBSTRUCTED AREAS THIS MAP COMPLIES WITH NATIONAL STANDARDS FOR MAP ACCURACY
IN AREAS OF DENSE VEGETATION WHERE THE GROUND IS OBSCURED FROM VIEW, CONTOURS MAY DEVIATE FROM CORRECT ELEVATION BY ONE HALF THE HEIGHT OF THE COVER

ALTERNATIVE I

MONTANA DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION
WATER RESOURCES DIVISION

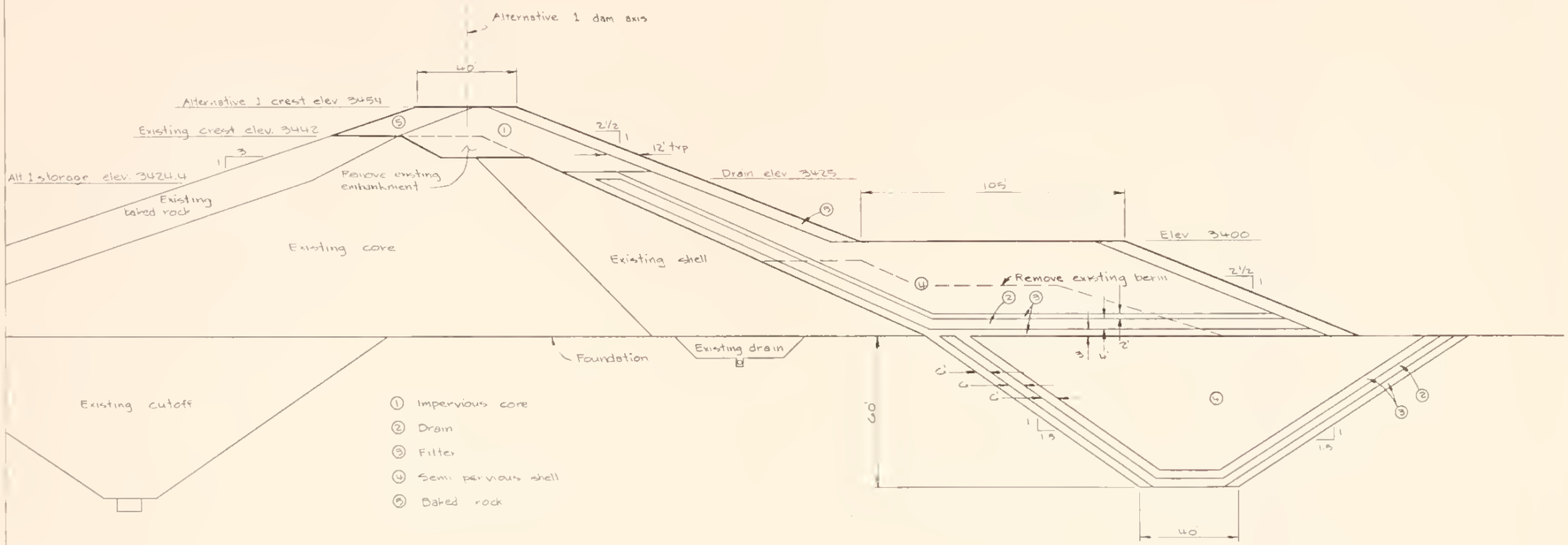
TONGUE RIVER PROJECT
MODIFICATION FEASIBILITY STUDY

STORAGE ELEVATION 3424.4
GENERAL PLAN

PROJ. NO.	1631
DRAWN BY	B.F.
APPD. BY	R.C.H.
DATE	2/24/76
SCALE	As Shown

R. C. HARLAN AND ASSOCIATES
88 NEW MONTGOMERY STREET
SAN FRANCISCO, CALIFORNIA 94105
(415) 788-6888

FIGURE 3



20 0 20 40 60

SCALE (feet)

ALTERNATIVE 1

MONTANA DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION
WATER RESOURCES DIVISION

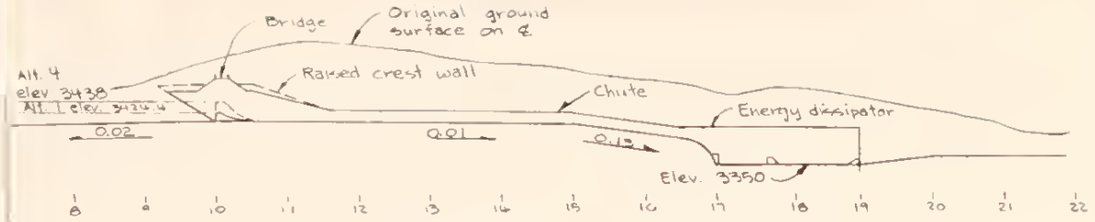
TONGUE RIVER PROJECT
MODIFICATION FEASIBILITY STUDY

STORAGE ELEVATION 3424.4
EMBANKMENT SECTION

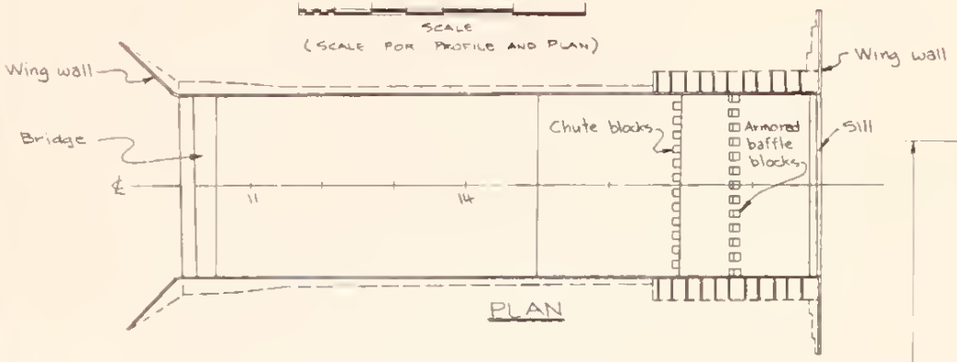
PROJ. NO.	1169.1
DRAWN BY	B.F.
TRACED BY	
DATE	10/29/76
SCALE	As Shown

R C HARLAN AND ASSOCIATES
50 NEW MONTGOMERY STREET
SAN FRANCISCO, CALIFORNIA 94105
(415) 788-4888

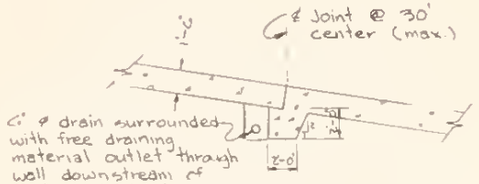
FIGURE 4



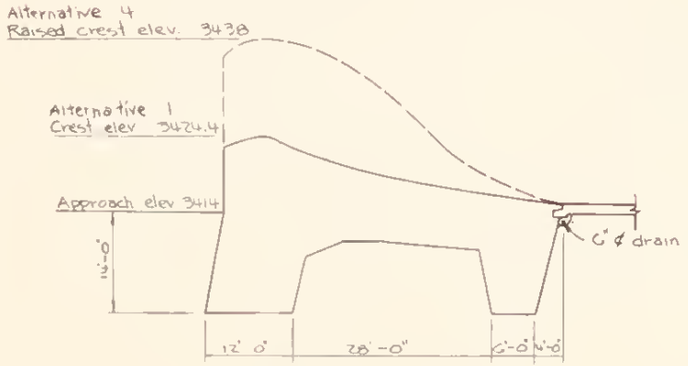
PROFILE



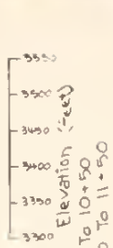
PLAN

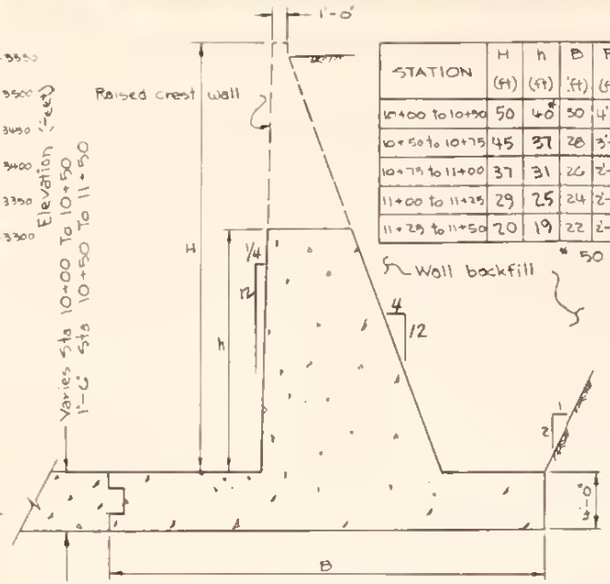

℄ Joint @ 30' center (max.)
6" ℄ drain surrounded with free draining material outlet through wall downstream of each slab joint
2'-0"

TRANSVERSE SLAB JOINT



CREST STRUCTURE

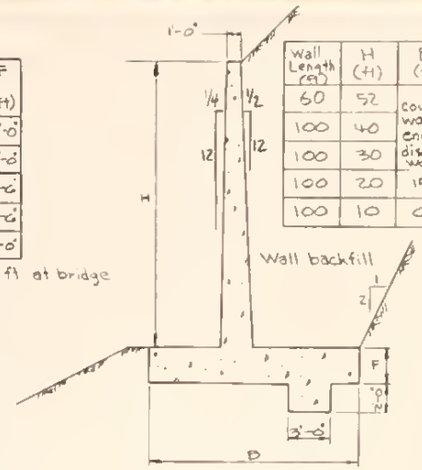




STATION	H (ft)	h (ft)	B (ft)	F (ft)
10+00 to 10+50	50	40*	30	4'-0"
10+50 to 10+75	45	37	28	3'-6"
10+75 to 11+00	37	31	26	2'-6"
11+00 to 11+25	29	25	24	2'-6"
11+25 to 11+50	20	19	22	2'-0"

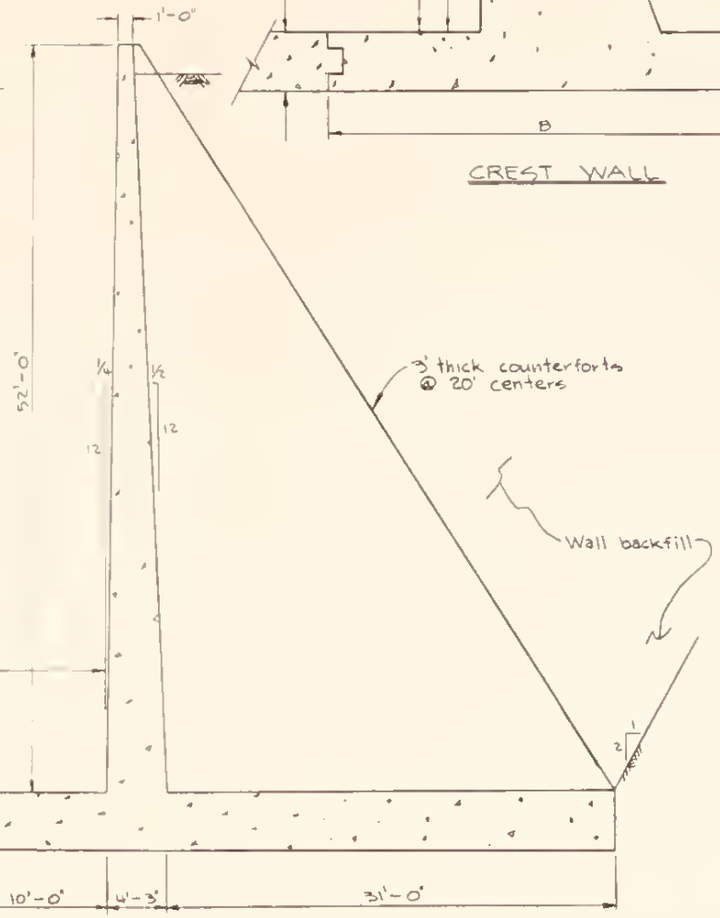
* 50 ft at bridge

CREST WALL

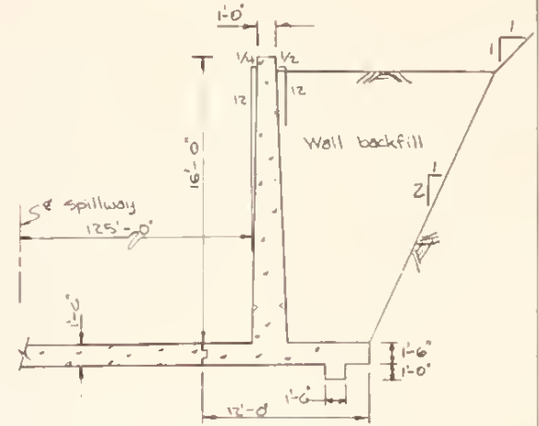


Wall Length (ft)	H (ft)	B (ft)	F (ft-in)
60	52	use counterforted wall - see energy dissipator wall	
100	40		
100	30		
100	20	15'	2'-6"
100	10	6'	1'-6"

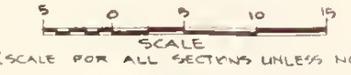
WING WALL



ENERGY DISSIPATOR WALL
STA 16+60 TO 19+00



CHUTE WALL
STA 11+50 TO 16+60



ALTERNATIVE 1 AND 4

MONTANA DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION
WATER RESOURCES DIVISION

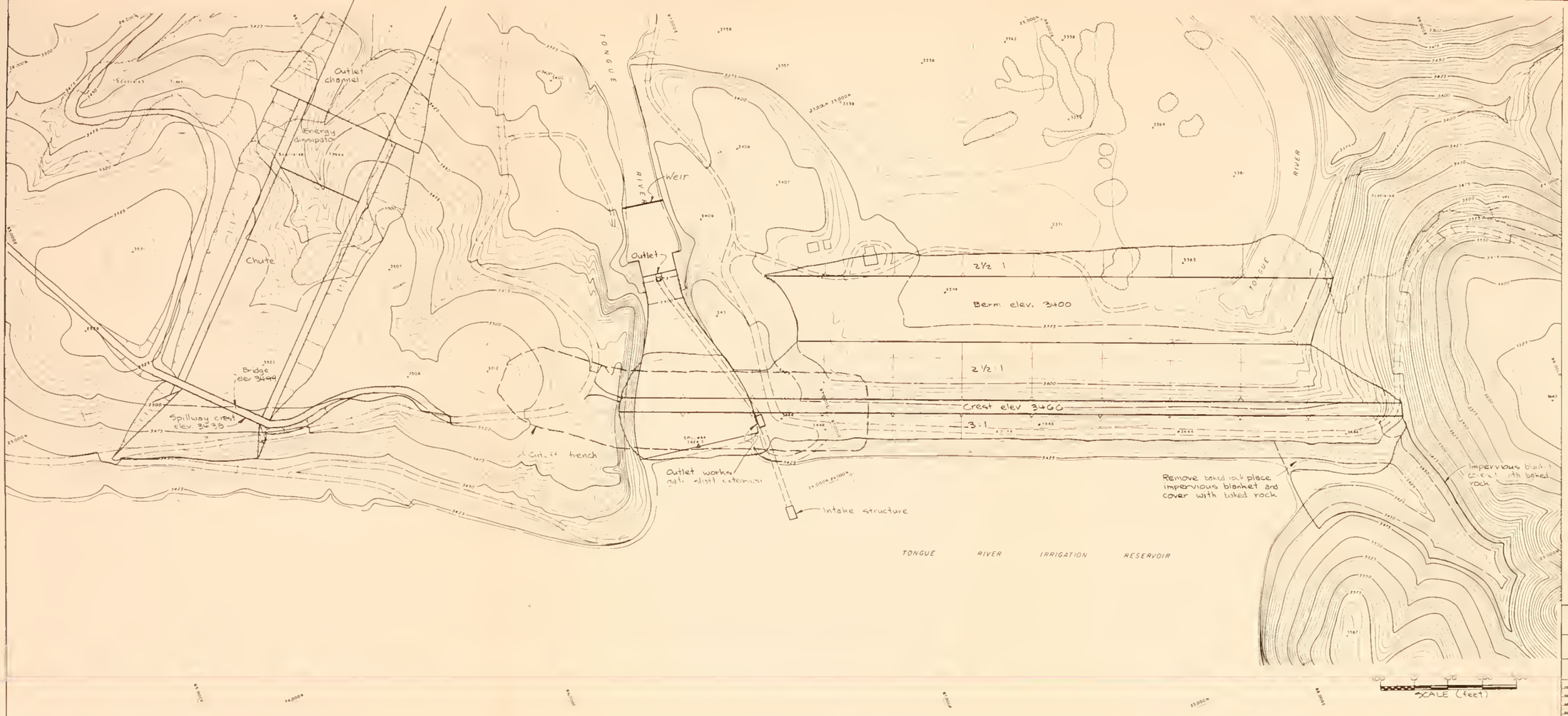
TONGUE RIVER PROJECT
MODIFICATION FEASIBILITY STUDY

STORAGE ELEVATION 3424.4 AND RAISE TO 3438
SPILLWAY

JOB NO.	167.1
DRAWN BY	B.E.
APP'D BY	R.C.H.
DATE	10/29/76
REVISED	

R. C. HARLAN AND ASSOCIATES
84 NEW MONTGOMERY STREET
SAN FRANCISCO, CALIFORNIA 94105
(415) 788-4880

FIGURE
5



NOTE
GRID IS 84338 ON LOCAL COORDINATE SYSTEM
FIELD SURVEY CONTROL BY R W TOWILL CORP
ELEVATIONS 343 BASED ON MEAN SEA LEVEL DATUM 1929 ADJ

NOTE
IN OPEN UNOBSTRUCTED AREAS THIS MAP COMPLIES WITH NATIONAL STANDARDS FOR MAP ACCURACY

IN AREAS OF DENSE VEGETATION WHERE THE GROUND IS OBSCURED FROM VIEW CONTOURS MAY DEVIATE FROM CORRECT ELEVATION BY ONE HALF THE HEIGHT OF THE DATUM

ALTERNATIVE 2

MONTANA DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION
WATER RESOURCES DIVISION

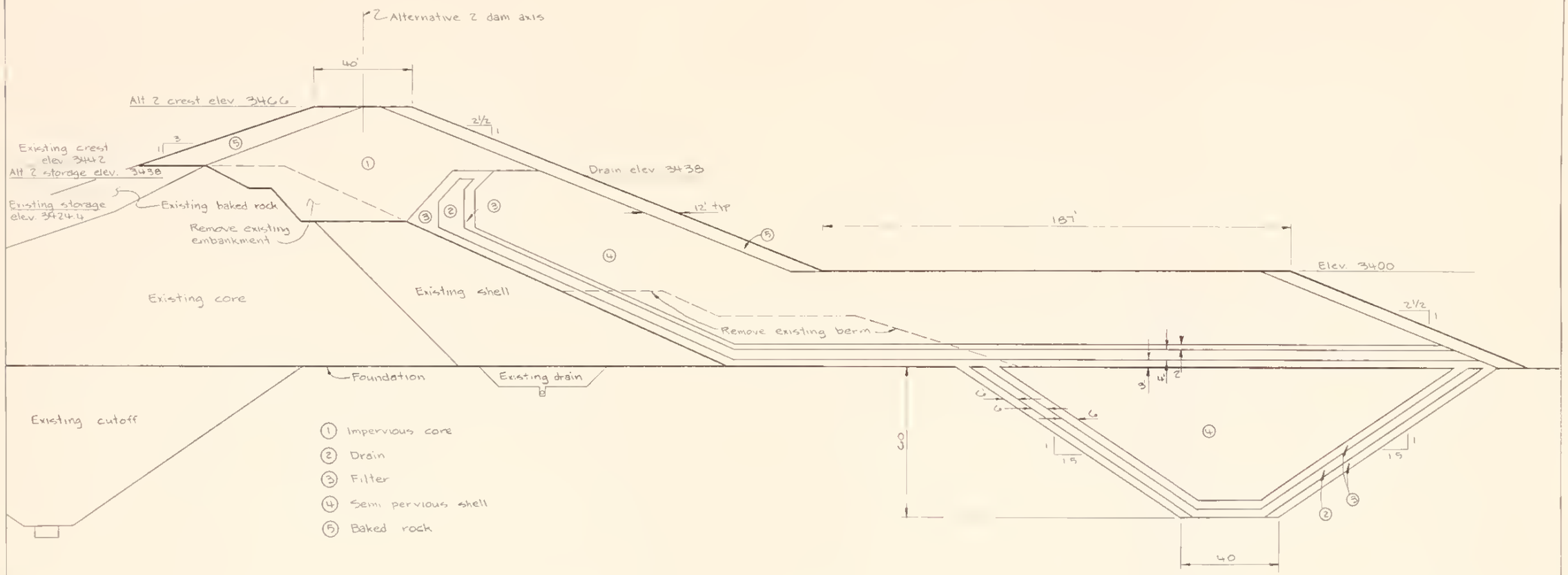
TONGUE RIVER PROJECT
MODIFICATION FEASIBILITY STUDY

STORAGE ELEVATION 3438

GENERAL PLAN

JOB NO	1691	
DRAWN BY	B.F.	R C HARLAN AND ASSOCIATES
APPROVED		68 NEW MONTGOMERY STREET
DATE	10/27/76	SAN FRANCISCO, CALIFORNIA 94105
SCALE	1" = 500'	(415) 788-3669

FIGURE 6



ALTERNATIVE 2

MONTANA DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION
WATER RESOURCES DIVISION

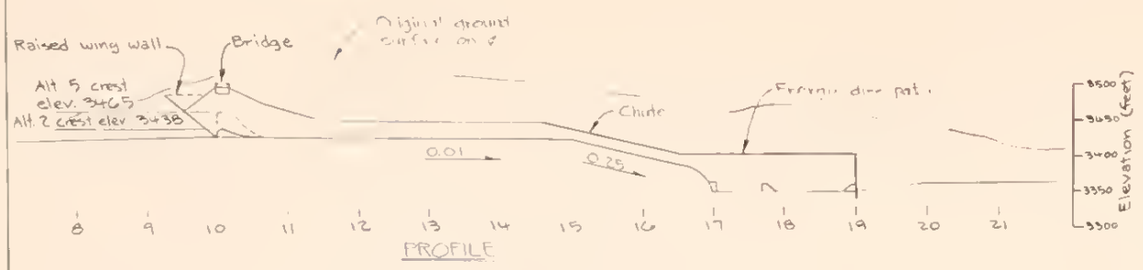
TONGUE RIVER PROJECT
MODIFICATION FEASIBILITY STUDY

STORAGE ELEVATION 3438
EMBANKMENT SECTION

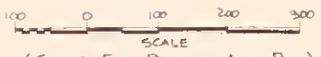
PROJ. NO.	1691
DESIGN BY	B.F.
APPD BY	R.H.
DATE	10/29/76
SCALE	As Shown

R. C. HARLAN AND ASSOCIATES
88 NEW MONTGOMERY STREET
SAN FRANCISCO, CALIFORNIA 94105
(415) 788 4888

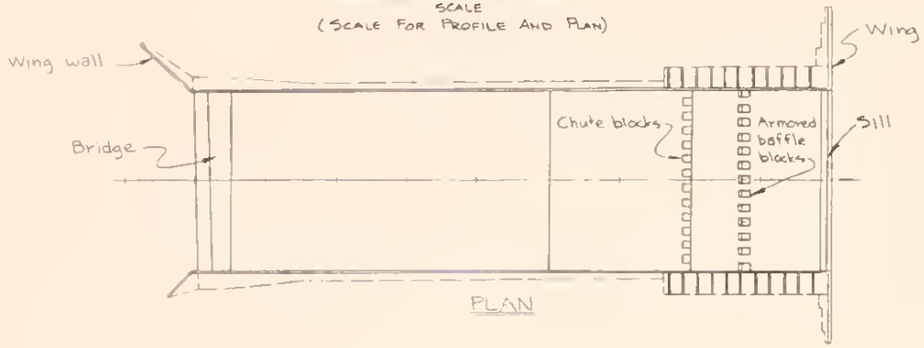
FIGURE
7



PROFILE



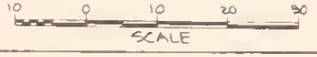
(SCALE FOR PROFILE AND PLAN)

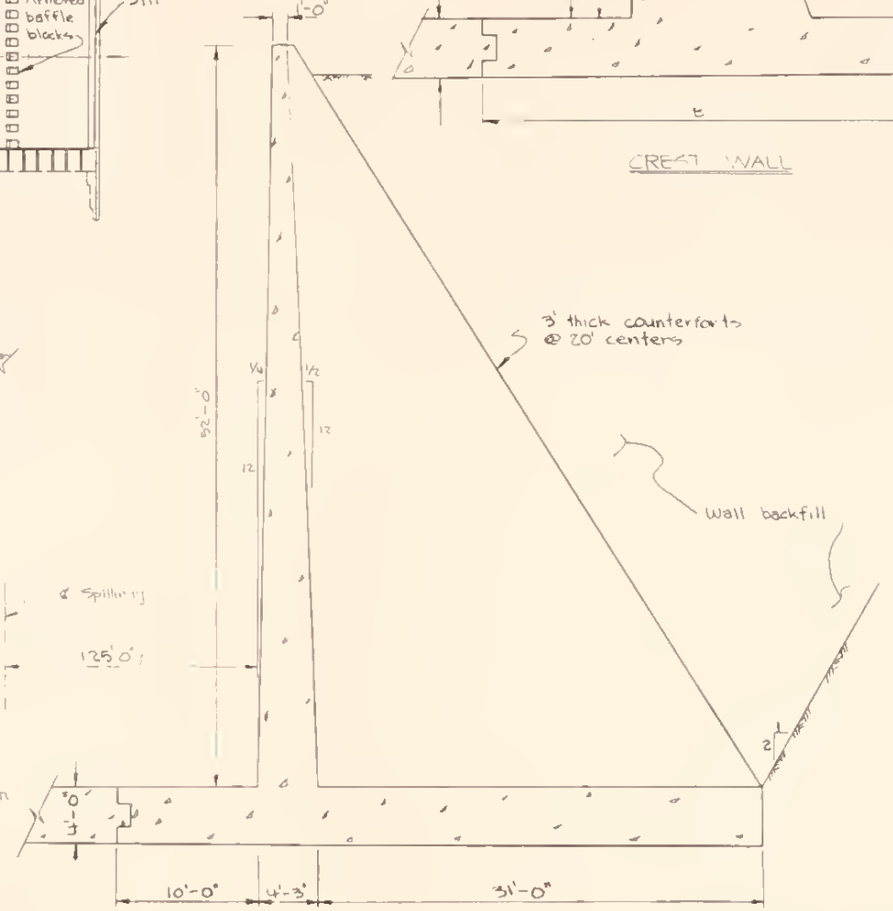


PLAN

TRANSVERSE SLAB JOINT

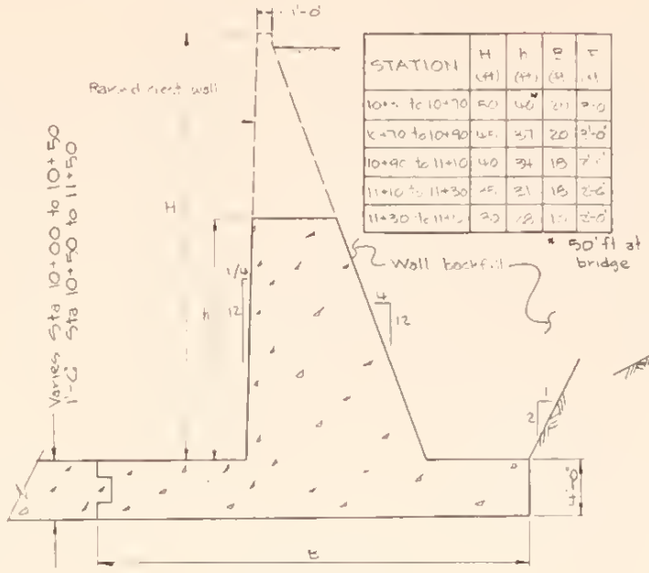
CREST STRUCTURE





ENERGY DISSIPATOR WALL
STA. 16+60 TO 19+00

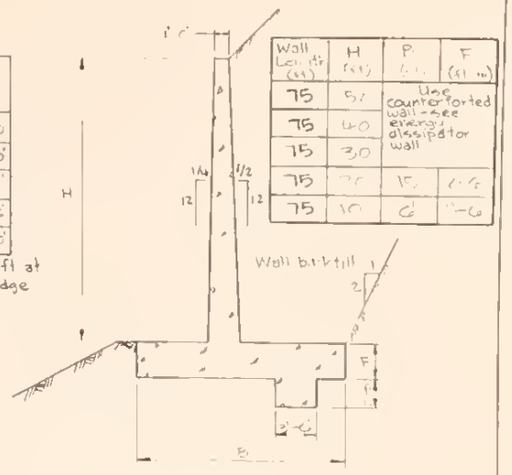
(SCALE FOR ALL SECTIONS OTHERWISE NOTED)



STATION	H (ft)	h (ft)	P (ft)	F (ft)
10+00 to 10+70	50	46	21	3'-0
10+70 to 10+90	48	44	20	2'-6"
10+90 to 11+10	40	34	18	2'-0"
11+10 to 11+30	28	22	18	2'-6"
11+30 to 11+50	20	18	12	2'-0"

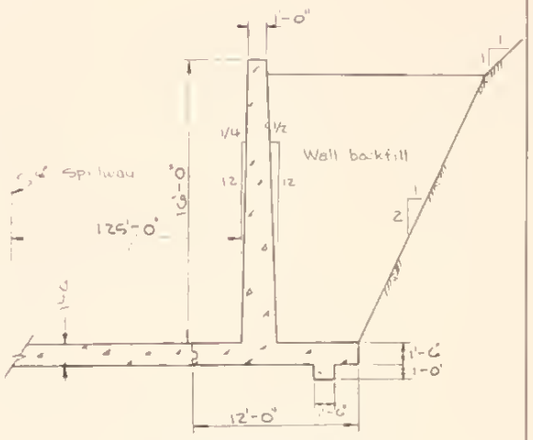
* 50' ft at bridge

CREST WALL



Wall Location (ft)	H (ft)	P (ft)	F (ft)
75	52	Use counterforted wall - see energy dissipator wall	
75	40		
75	30		
75	20	15	1'-6
75	10	6	1'-6

WING WALL



CHUTE WALL
STA 11+50 TO 16+60

ALTERNATIVE 2 AND 5

MONTANA DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION
WATER RESOURCES DIVISION

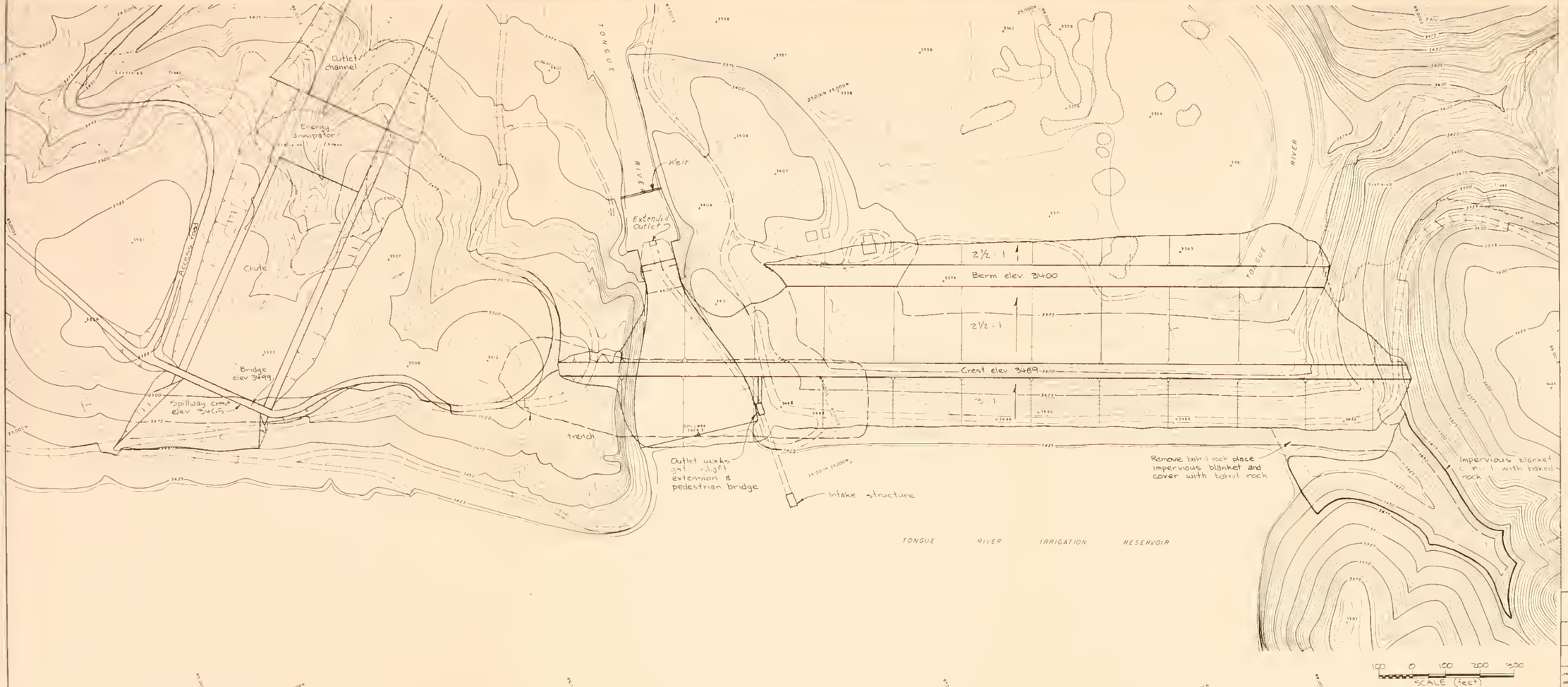
TONGUE RIVER PROJECT
MODIFICATION FEASIBILITY STUDY

STORAGE ELEVATION 3438 AND RAISE TO 3465
SPILLWAY

PROJ. NO.	1169.1
DRAWN BY	B.F.
APP'D BY	R.H.
DATE	2/29/76
SCALE	AS SHOWN

R. C. HARLAN AND ASSOCIATES
99 NEW MONTGOMERY ST. 827
SAN FRANCISCO, CALIFORNIA 94105
(415) 788-4888

FIGURE
8



NOTE
GRID IS BASED ON LOCAL COORDINATE SYSTEM
FIELD SURVEY CONTROL BY R W TOMILL CORP
ELEVATIONS ARE BASED ON MEAN SEA LEVEL DATUM 1954 NGS

NOTE
IN OPEN UNOBSTRUCTED AREAS, THIS MAP COMPLIES WITH NATIONAL STANDARDS FOR MAP ACCURACY
IN AREAS OF DENSE VEGETATION WHERE THE GROUND IS OBSCURED FROM VIEW, CONTOURS MAY DEVIATE FROM CORRECT ELEVATION BY ONE HALF THE HEIGHT OF THE COVER

ALTERNATIVE 3 AND 5

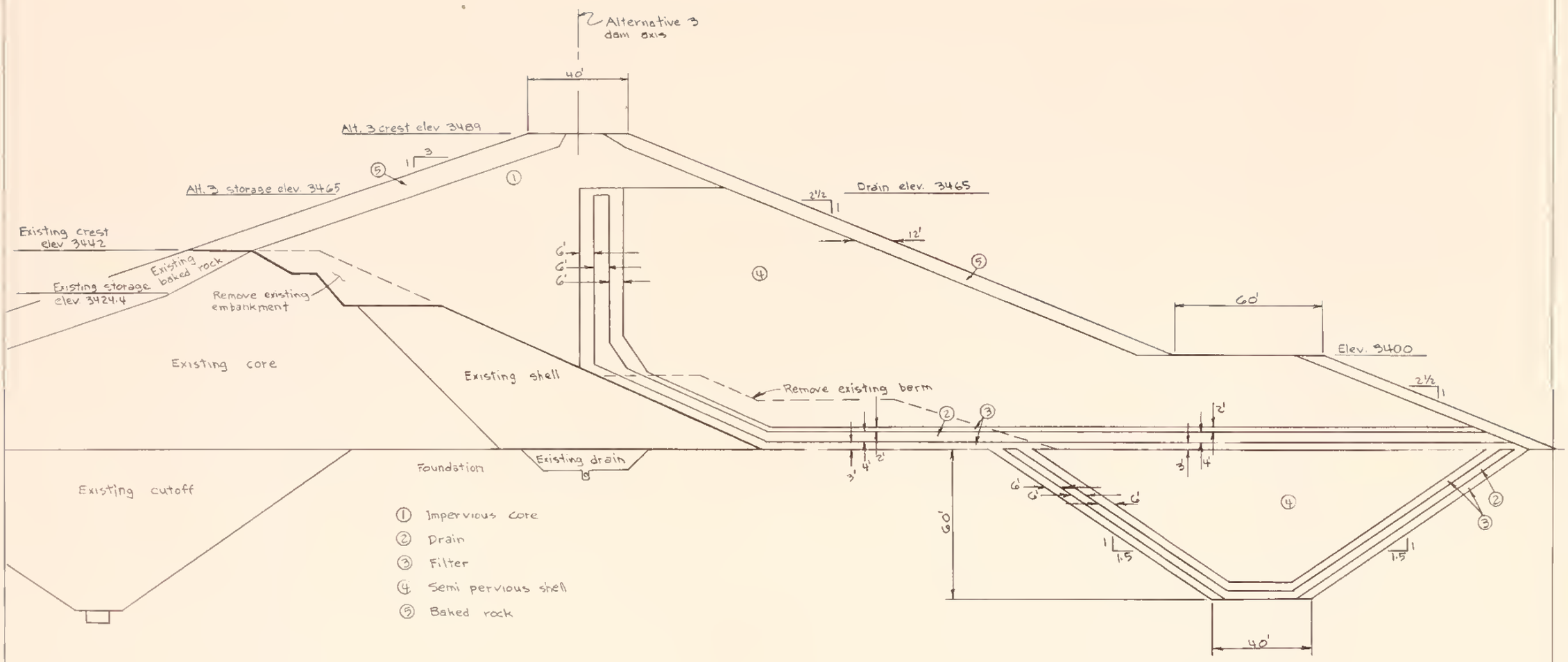
MONTANA DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION
WATER RESOURCES DIVISION

TONGUE RIVER PROJECT
MODIFICATION FEASIBILITY STUDY

STORAGE ELEVATION 3465
GENERAL PLAN

PROJ. NO. 169	R C HARLAN AND ASSOCIATES
DRAWN BY TF	
APP'D BY CHF	
DATE 5/23/74	
REVISED PJS 5/24/74	

FIGURE
9



ALTERNATIVE 3

MONTANA DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION
WATER RESOURCES DIVISION

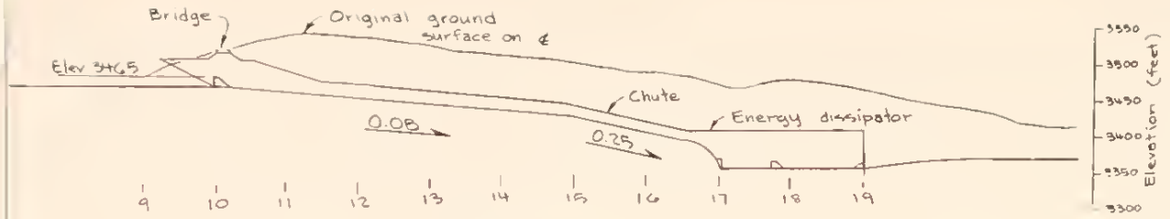
TONGUE RIVER PROJECT
MODIFICATION FEASIBILITY STUDY

STORAGE ELEVATION 3465
EMBANKMENT SECTION

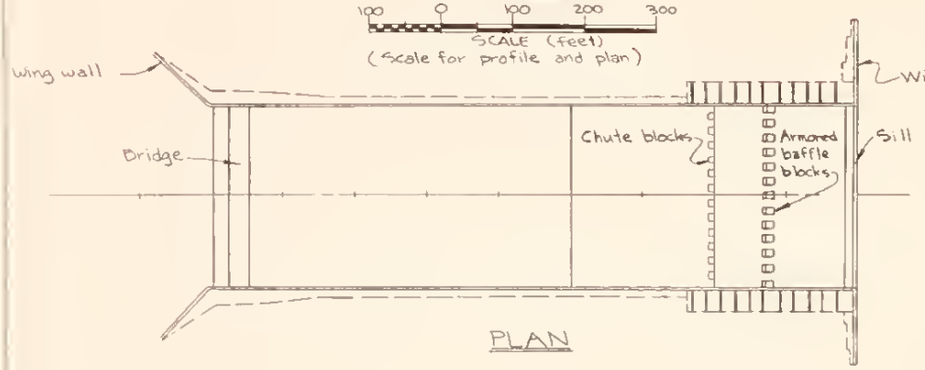
PROJ. NO.	1691
DRAWN BY	B.E.
APP'D BY	RCH
DATE	12/29/76
SCALE	As Shown

R. C. HARLAN AND ASSOCIATES
82 NEW MONTGOMERY STREET
SAN FRANCISCO, CALIFORNIA 94105
(415) 788-4080

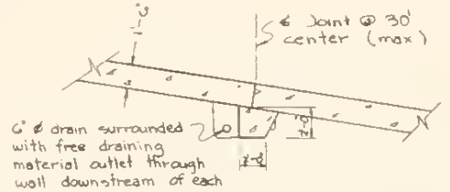
FIGURE
10



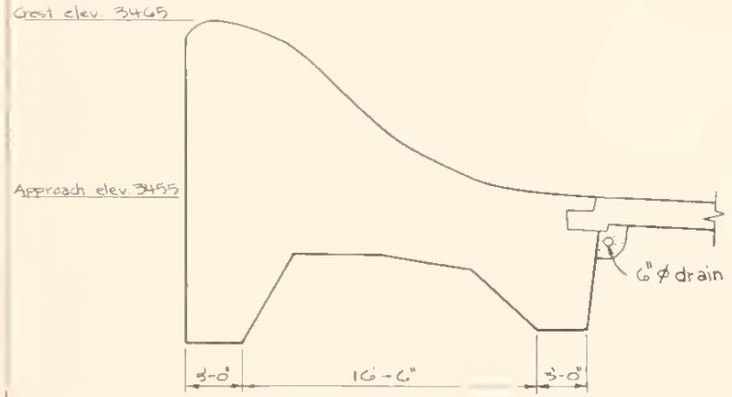
PROFILE



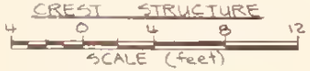
PLAN

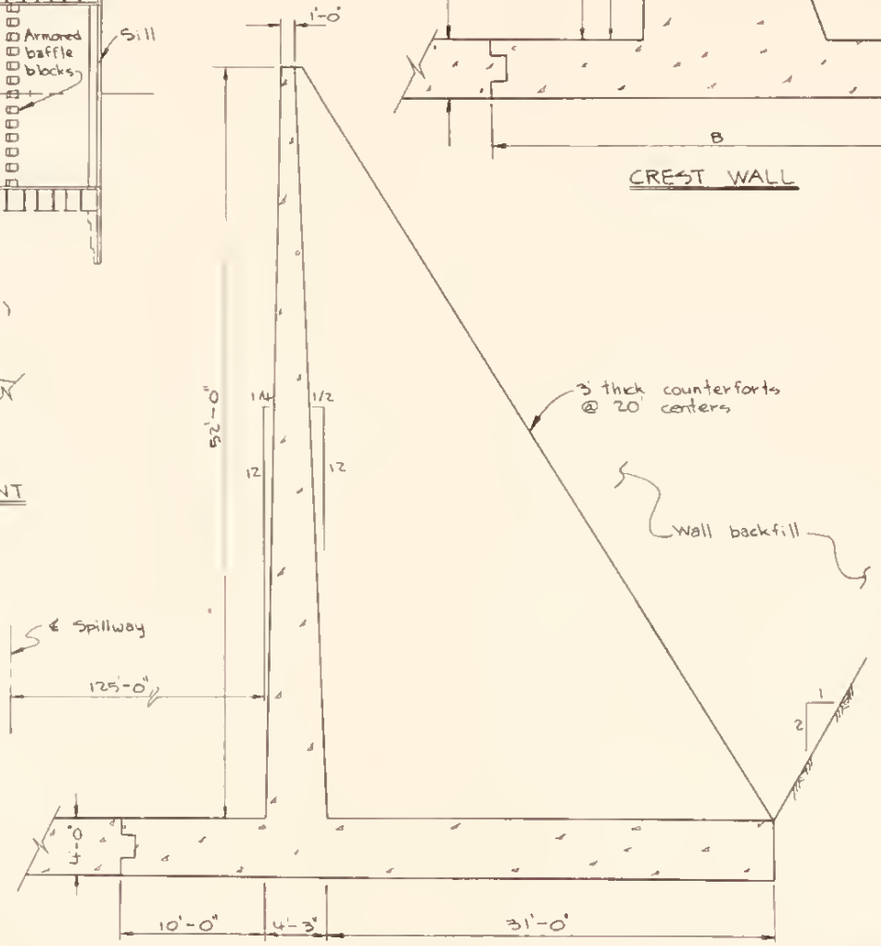


TRANSVERSE SLAB JOINT

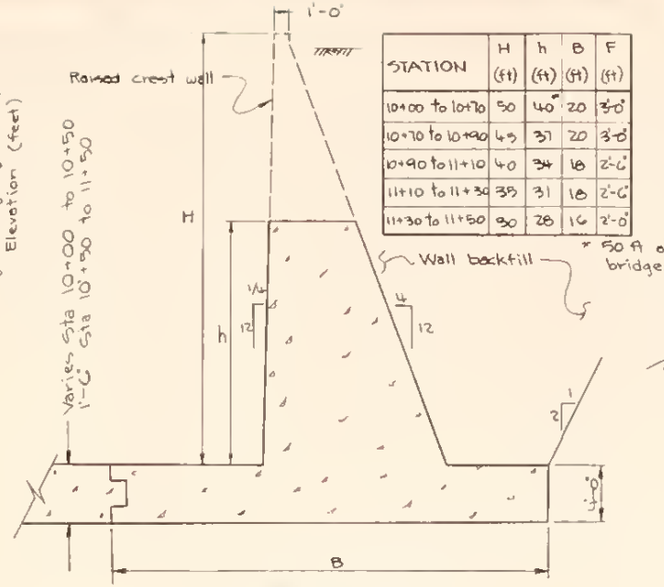


CREST STRUCTURE





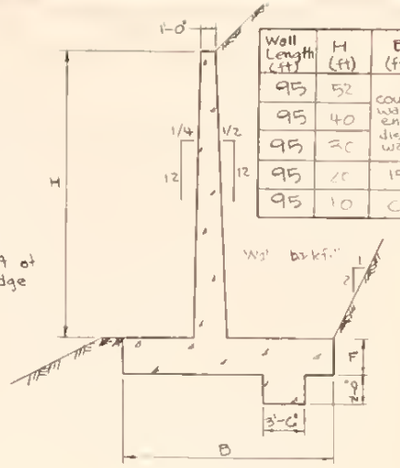
ENERGY DISSIPATOR WALL
STA 16+60 TO 19+00



STATION	H (ft)	h (ft)	B (ft)	F (ft)
10+00 to 10+70	50	40	20	3'-0"
10+70 to 10+90	45	37	20	3'-0"
10+90 to 11+10	40	34	18	2'-6"
11+10 to 11+30	35	31	18	2'-6"
11+30 to 11+50	30	28	16	2'-0"

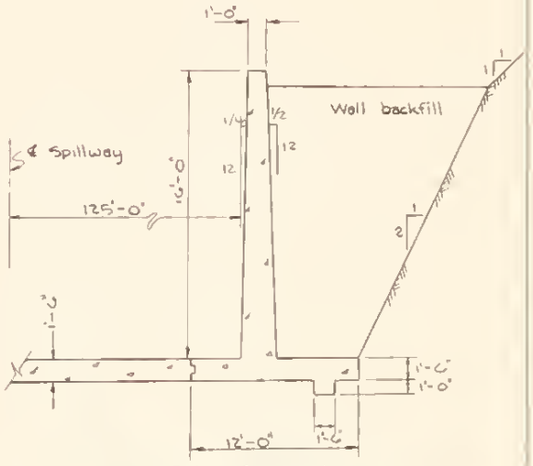
* 50 ft of bridge

CREST WALL



Wall Length (ft)	H (ft)	B (ft)	F (ft)
95	52	Use counterforted wall - see energy dissipator wall	
95	40		
95	30		
95	20	15'	1'-6"
95	10	6'	1'-6"

WING WALL



CHUTE WALL
STA 11+50 TO 16+60

ALTERNATIVE 3

MONTANA DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION
WATER RESOURCES DIVISION

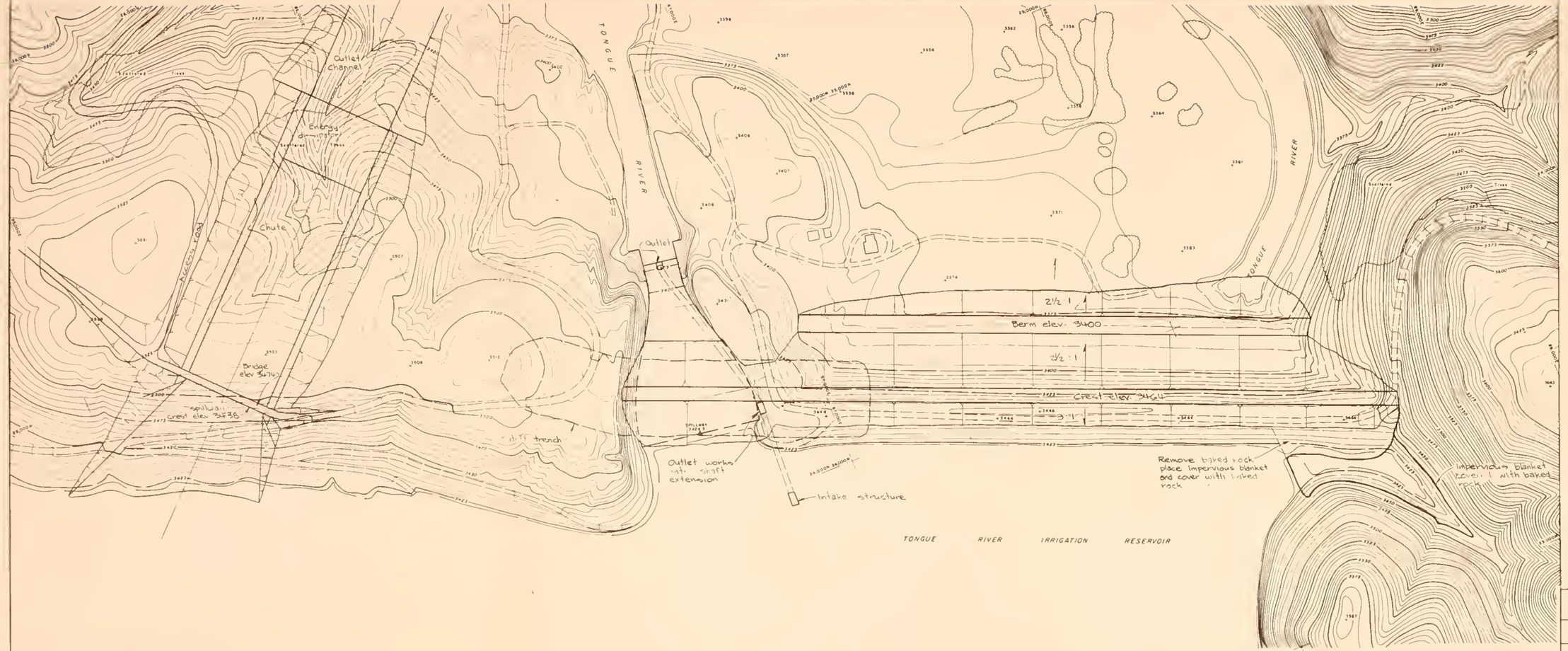
TONGUE RIVER PROJECT
MODIFICATION FEASIBILITY STUDY

STORAGE ELEVATION 3465
SPILLWAY

PROJ. NO.	169.1
DRAWN BY	B.F.
APPD. BY	R.H.
DATE	10/29/76
SCALE	As Shown

R C HARLAN AND ASSOCIATES
99 4th MONTGOMERY STREET
SAN FRANCISCO, CALIFORNIA 94109
(415) 392-0200

FIGURE
11



NOTE
APIE IS BASED ON LOCAL COORDINATE SYSTEM
FIELD SURVEY CONTROL BY C.B. TOWILL CORP.
ELEVATIONS ARE BASED ON MEAN SEA LEVEL DATUM 1929 ADJ.

NOTE
IN OPEN UNOBSTRUCTED AREAS, THIS MAP COMPLIES WITH NATIONAL STANDARDS FOR MAP ACCURACY

IN AREAS OF DENSE VEGETATION WHERE THE GROUND IS UNDISCERNIBLE FROM AIR, CONTOURS MAY DEVIATE FROM CORRECT ELEVATIONS BY NOT MORE THAN HALF THE HEIGHT OF THE COVER

ALTERNATIVE 4

MONTANA DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION
WATER RESOURCES DIVISION

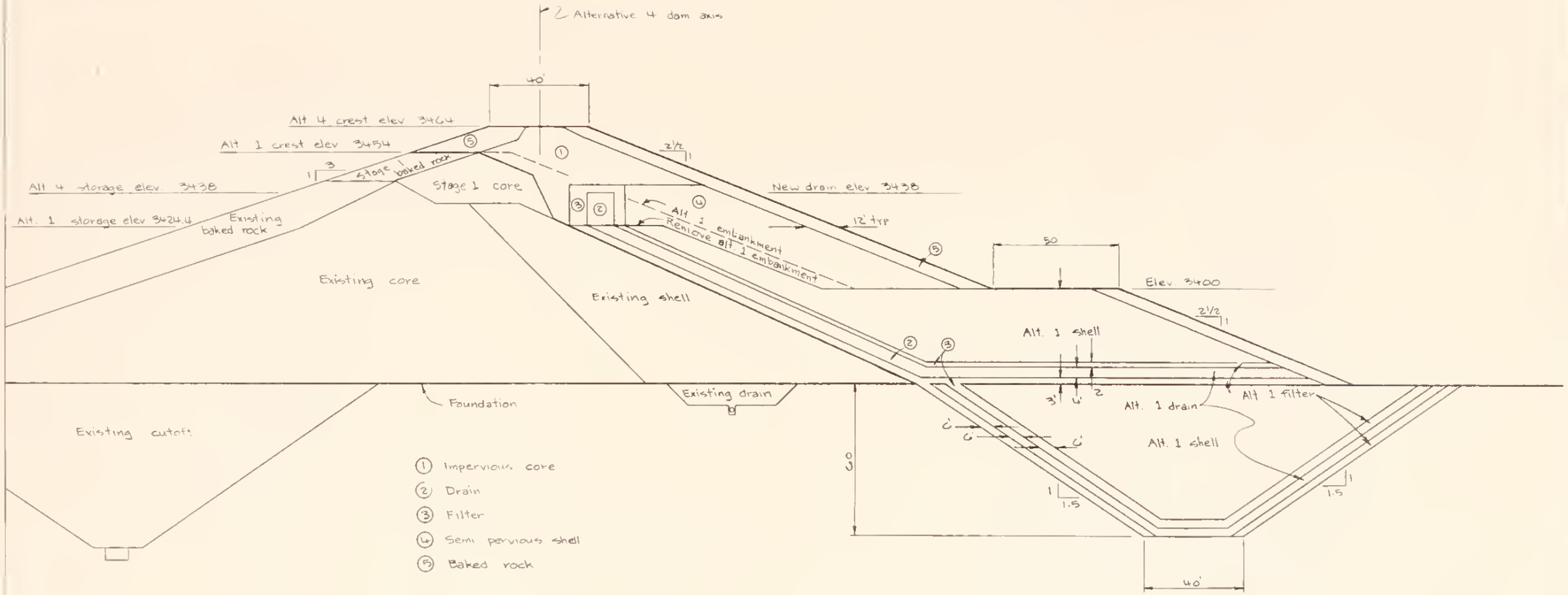
TONGUE RIVER PROJECT
MODIFICATION FEASIBILITY STUDY

STORAGE ELEVATION 3438
GENERAL PLAN

JOB NO.	1691
DRAWN BY	BF
CHK'D BY	
DATE	10/29/76
SCALE	As Shown

R. C. HARLAN AND ASSOCIATES
SAN FRANCISCO, CALIFORNIA

FIGURE 12



20 0 20 40 60
SCALE (feet)

ALTERNATIVE 4

MONTANA DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION
WATER RESOURCES DIVISION

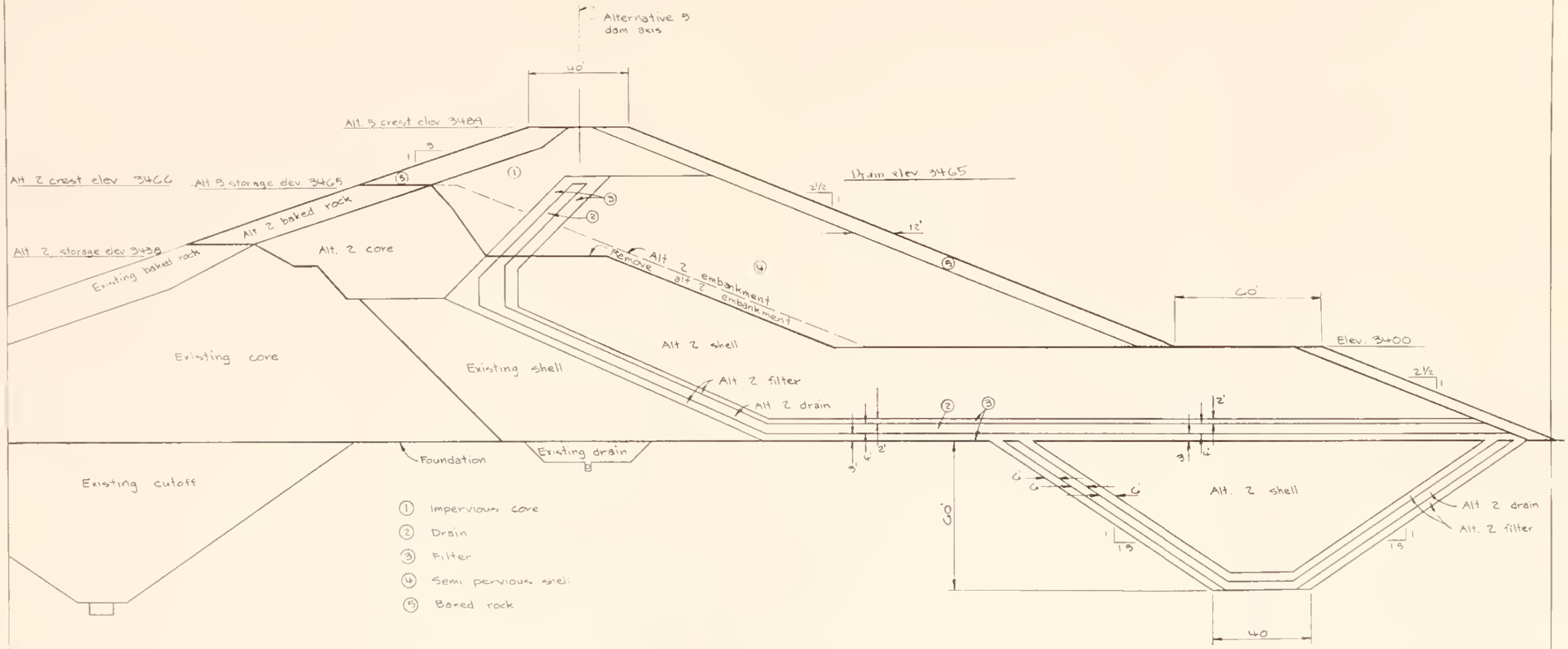
TONGUE RIVER PROJECT
MODIFICATION FEASIBILITY STUDY

STORAGE ELEVATION RAISE 3424.4 TO 3438
EMBANKMENT SECTION

PROJ. NO.	1691
DRAWN BY	B.F.
APP'D BY	R.C.H.
DATE	10/29/76
SCALE	As Shown

R. C. HARLAN AND ASSOCIATES
88 NEW MONTGOMERY STREET
SAN FRANCISCO, CALIFORNIA 94105
(415) 788-4666

FIGURE
13



ALTERNATIVE 5

MONTANA DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION
WATER RESOURCES DIVISION

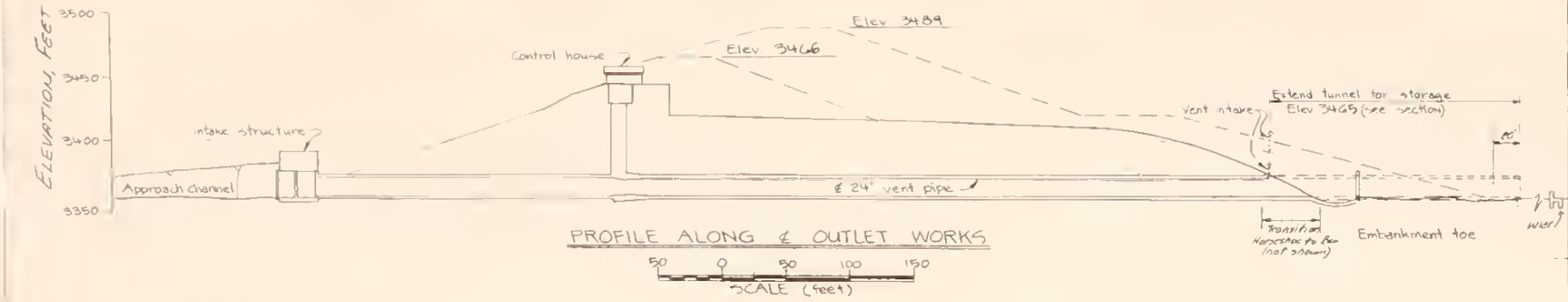
TONGUE RIVER PROJECT
MODIFICATION FEASIBILITY STUDY

STORAGE ELEVATION RAISE 3438 TO 3465
EMBANKMENT SECTION

PROJ. NO.	169-1
DRAWN BY	B.F.
APP'D BY	R.C.H.
DATE	1/29/76
SCALE	As Shown

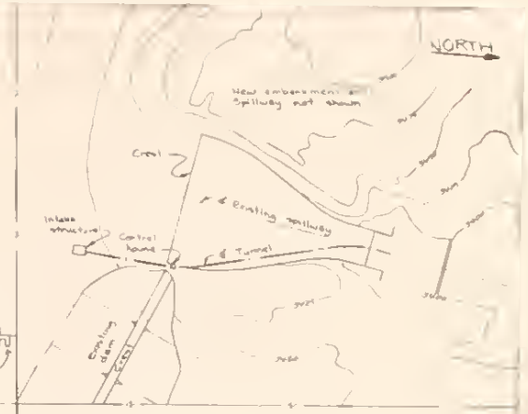
R. C. HARLAN AND ASSOCIATES
88 NEW MONTGOMERY STREET
SAN FRANCISCO, CALIFORNIA 94105
(415) 788-4000

FIGURE
14



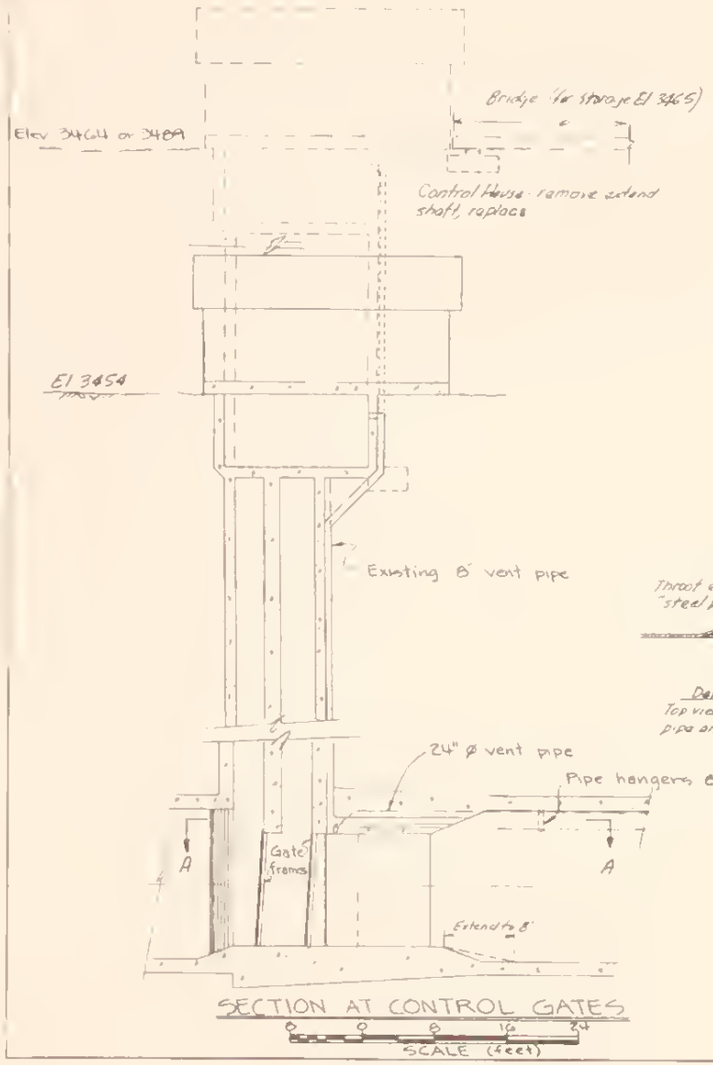
PROFILE ALONG ℄ OUTLET WORKS

SCALE (feet)



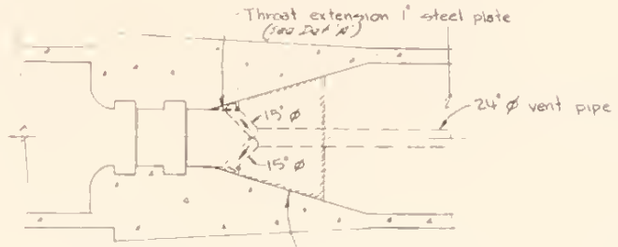
OUTLET WORKS PLAN

SCALE (feet)



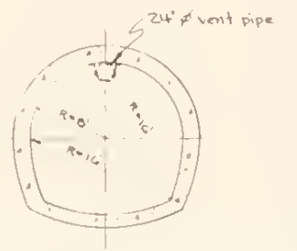
SECTION AT CONTROL GATES

SCALE (feet)



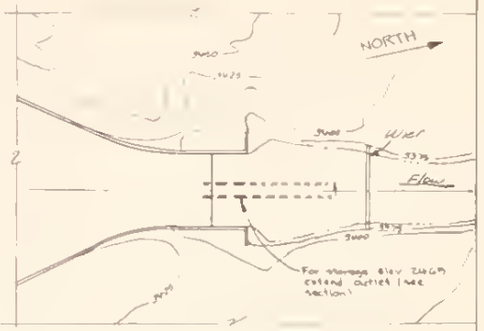
SECTION A-A

SCALE (feet)



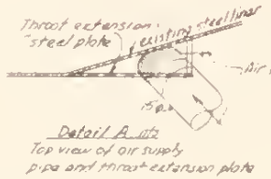
TYPICAL TUNNEL SECTION

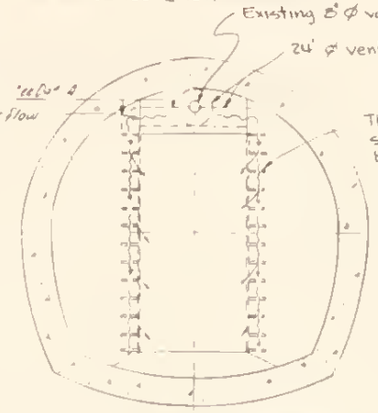
SCALE (feet)



DISCHARGE AREA PLAN

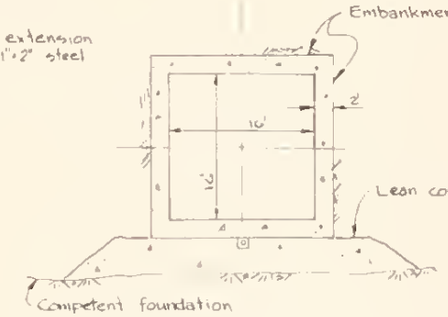
SCALE (feet)


Throat extension steel plate
existing steel liner
Air flow
Detail A
Top view of air supply pipe and throat extension plate



VIEW OF CONTROL SECTION LOOKING UPSTREAM

SCALE (feet)



OUTLET WORKS EXTENSION

(APPLIES ONLY TO STORAGE ELEV 3465)

SCALE (feet)

MONTANA DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION
WATER RESOURCES DIVISION

TONGUE RIVER PROJECT
MODIFICATION FEASIBILITY STUDY

OUTLET WORKS MODIFICATIONS

PROJ. NO.	169.1
DRAWN BY	B.F.
APP'D BY	K.H.
DATE	10/29/76
REVISED	As Shown

R. C. HARLAN AND ASSOCIATES
111 NEW MONTGOMERY STREET
SAN FRANCISCO, CALIFORNIA 94105
(415) 982-2889

FIGURE 15

A P P E N D I X

HISTORY OF THE TONGUE RIVER PROJECT*

"The Montana legislature in 1967 authorized the Montana Water Resources Board to carry out investigations and engineering for the Tongue River Project to develop industrial water supplies for use in southeastern Montana. On May 25, 1967, a contract was executed between the Montana Water Resources Board and Bechtel Corporation to carry out the investigations and engineering. At that time it was anticipated that the storage required for the project would be about 150,000 acre feet to be accomplished by raising the existing Tongue River Dam, and/or building a new dam downstream.

"As a first step in the engineering studies, the determination of the relationship between firm water supply yield and reservoir sizing was undertaken.

"Historical flow records for the Tongue River near the state line are available since 1929, providing an adequate basis for water yield studies. However, the Tongue River, a major tributary of the Yellowstone River, flows from Wyoming into Montana and both of these states share in rights to use its waters.

"In order to provide a basis for usage of waters of the major rivers which flow from Wyoming into Montana, these two states concluded the Yellowstone River Compact in 1950. Before yield studies could be made, it was necessary to determine Montana's share of the unused and unappropriated water in the Tongue River.

"On June 8, 1967, the Montana Water Resources Board authorized Bechtel Corporation to proceed with a study for determination of the unused and unappropriated water in the Tongue River for allocation under the Yellowstone River Compact. That study included:

1. Collection and evaluation of basic streamflow data.

2. Collection and evaluation of water rights data in both Montana and Wyoming.

---

* Excerpts from Basic Design Report - Tongue River Project Bechtel, Incorporated 1969

3. Field investigation of water use and administration.

4. Determination of supplemental water requirements, and

5. Analysis of data and determination of unused and unappropriated water.

"After intensive study, analysis, review by the Montana Water Resources Board and revision, a draft Water Allocation study report was presented to the Yellowstone River Compact commission at Sheridan, Wyoming, on December 19, 1967. On the basis of this initial water allocation study, yield studies showed that the maximum yield from the Tongue River which could be developed from water allocated to Montana was 72,000 acre feet a year and a gross storage of 245,000 acre feet was required to develop that yield.

"Following a presentation of the allocation and yield studies to the Board in Billings on January 4, 1968, further studies were made by the Board on the allocation study. Following a meeting between the Montana Water Resources Board Director and the Wyoming State Engineer on January 24, 1968, it was determined by the Board that the storage rights of the existing Tongue River Reservoir be considered as not being subject to allocation regardless of possible future changes of actual use. The effective result of this change of interpretation was to increase the water which could be developed by Montana and therefore the yield of the project. Under this revised allocation it was determined that a maximum yield of 112,000 acre feet annually could be developed by providing some 450,000 acre feet of gross storage.

"A revised draft of the Water Allocation study report was reviewed with the Board and with members of the legislative council on April 5, 1968 at Helena. The Water Allocation Study report was submitted to the Board in final form on April 22, 1968.

"The Water Allocation Study presented two "allocations." The first adhering strictly to the compact provisions, particularly with respect to reservations of supplemental water, leads to conclusions which are believed unrealistic. The second "allocation" was made based on analysis and jugment of realistic future conditions in the Tongue River Basin. The Board concurred in Bechtel's recommendation that the project be sized on the basis of the "realistic allocation." The yield studies based on that allocation are described later in this report.

"During the summer and autumn of 1967, field investigations were carried out to provide data for design of the increased reservoir, either by raising the existing dam, or by constructing a new dam downstream. Foundation explorations were carried out at the existing dam and at the Oxbow site, located as shown on Drawing No. 6694-11-003. Because of unfavorable foundation conditions at the Oxbow site, another site, called the Four Mile Creek site, was also explored. Borrow explorations were also carried out at this time to locate and obtain samples of earth construction materials.

"During the fall of 1967 and the early winter of 1967-1968, design studies for raising the existing dam or constructing a new one downstream were carried out. Based on the initial allocation and yield studies, preliminary designs providing total storage of 245,000 acre feet were undertaken. During this period the Board determined that storage of water in Wyoming should be avoided. This criterion effectively limits the storage to about Elevation 3441, which is the approximate elevation of the Tongue River streambed at the State Line.

"In January 1968, after preliminary designs had been well advanced, the revision of the allocation and yield studies required further substantial changes in the scope of the project. Studies of foundation conditions and raising the existing Tongue River Dam indicated that only a moderate raise would be possible. The yield studies based on the revised and "realistic allocation" study have shown that some 450,000 acre-feet gross storage would be required for development of the 112,000 acre feet per year firm yield. Only about 140,000 acre feet of storage would be available at the existing dam site, yielding about 72,000 acre feet per year. The dam site near the Four Mile Creek confluence with the Tongue River is the furthest downstream feasible dam site before the Tongue River canyon opens out into a broader valley. Therefore, it is the site with the greatest storage potential without storing water above the State Line into Wyoming.

"A dam at the Four Mile Creek site would store water to the same elevation as the existing dam raised to its greatest feasible height. However, the Four Mile Creek site would provide substantially more yield. If the existing dam were raised, at an estimated direct construction cost at 1968 price level of about $4,000,000 and additional water needed at a later date, the raised dam would be inundated and the investment would not be

fully recovered. Therefore, it was recommended to the Board that a dam be built at the Four Mile Creek site and raised later if necessary to provide greater storage and greater yield.

"On April 5, 1968, the Board directed Bechtel to proceed with design of a dam at the Four Mile Creek site, later designated as the High Tongue River Dam. The Board directed that the dam have a maximum storage Elevation 3438, about three and one-half feet below the State Line streambed elevation. Although this will prevent storage of water in Wyoming, floods which may occur when the reservoir is nearly fully, will cause ponding of water in Wyoming. The Storage Elevation 3438 will provide gross storage of 320,000 acre feet with a corresponding yield of 100,000 acre feet annually, part of which is for agricultural use under existing committments.

"There is a possibility that a dam may be constructed for industrial purposes near the State Line in Wyoming. Such a development is considered reasonable because of physical feasibility of a dam site at that location and all Tongue River drainage in Wyoming would be tributary to such a reservoir. Such construction would make possible raising High Tongue River Dam if suitable arrangements could be made to back water up on the downstream side of the new dam. The Board therefore directed that the High Tongue River dam be designed so that it could be raised to storage elevation 3453, to provide 450,000 acre feet storage with a corresponding firm yield of 112,000 acre feet annually."

SUMMARY OF WATER SUPPLY STUDIES*

"General

"In order to determine the field yield of the Tongue River Project and the correlated reservoir storage capacity, a series of studies was made. These studies were based on an allocation of water under the Yellowstone River Compact. First, the historical inflow to the project area was determined. Second, the probable future depletion of flow above the state line by Wyoming under the provisions of the Yellowstone River Compact was subtracted from the historical inflow. Third, downstream releases for prior adjudicated rights on the Tongue River were deducted from the inflow. Fourth, the remaining water, called the storable inflow, was analyzed on a time sequence basis to determine the variation of the minimum storable inflow with time. Fifth, the minimum storable inflow was analyzed against time, evaporation and storage in order to evaluate the correlated firm water yield and required storage.

"The water supply studies for the Tongue River Project are based on the "Water Allocation Study" report which developed the historical sequence of unused and unappropriate flows which could be allocated to Montana. That report was submitted to the Montana Water Resources Board on April 22, 1968 by Bechtel Corporation. The yield studies are based on the "Realistic Allocation" described in that report."

"Historical Inflow to the Tongue River Project

"Inflow to the Tongue River Project is measured by the gage - "Tongue River at State Line." This gaging station was installed in 1960 but the record has been extended back to 1945 by use of the records from the gages "Tongue River at Tongue River Dam and Tongue River Reservoir End-of-Month Contents." This extended record was then modified as described in the "Water Allocation Study" report. First, the record was reduced to reflect the existence of the 1966 level of rights throughout the entire period. This was done on the "Part 2 - Wyoming" sheets in the "Water Allocation Study."

"Future Depletion in Wyoming

"The modified historical record was further reduced to account for the use of supplemental and surplus water in Wyoming on the basis of the "Realistic

*Excerpts from Bechtel's Basic Design Report

Allocation." The record of flow at the State Line gage reflecting the 1966 level of rights and realistic development of surplus and supplemental water in Wyoming is developed on the "Part 2 - Wyoming" sheets under the "Realistic Allocation." Wyoming's forty percent allocation of the unused and unappropriated water in the Tongue River, reduced for the post-1950 rights satisfied, was also deducted from the inflow. Wyoming's 40% share of the unused and unappropriated water was determined on the "Part 3 - Unused and Unappropriated Water" sheets under the "Realistic Allocation." The total for any year was assumed to be used for industrial purposes with annual consumption of 90% or 7.5% in each of the twelve months.

"Required Releases

"The decreed rights downstream of the Tongue River Project total 414.9 cfs. In addition to 30 cfs decreed rights, 60 cfs have been allotted to the Northern Cheyenne Indian Reservation as an allowance for water supply for their reserved lands as described in the "Water Allocation Study" report. This total of 475 cfs of prior rights are active during the irrigation season - May through September.

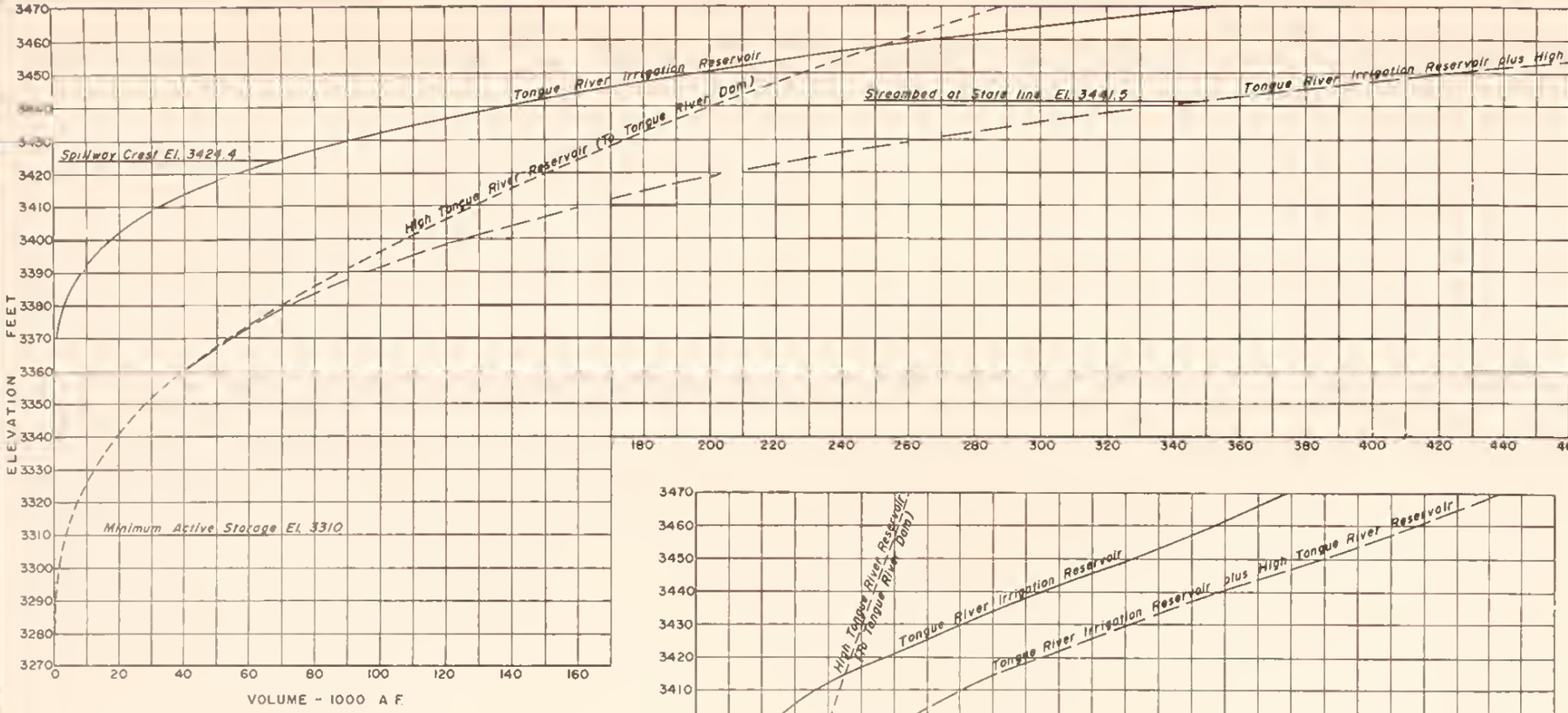
"In the non-irrigation months, releases are required for stock water and for prevention of ice jams. This release has historically been the inflow to the reservoir up to 10,000 acre feet per month (equivalent to 167 cfs continuously). The minimum release required for fish and municipal uses is understood to be 35 cfs. An October through April average release of 75 cfs is judged necessary to provide a live stream and prevent ice jams.

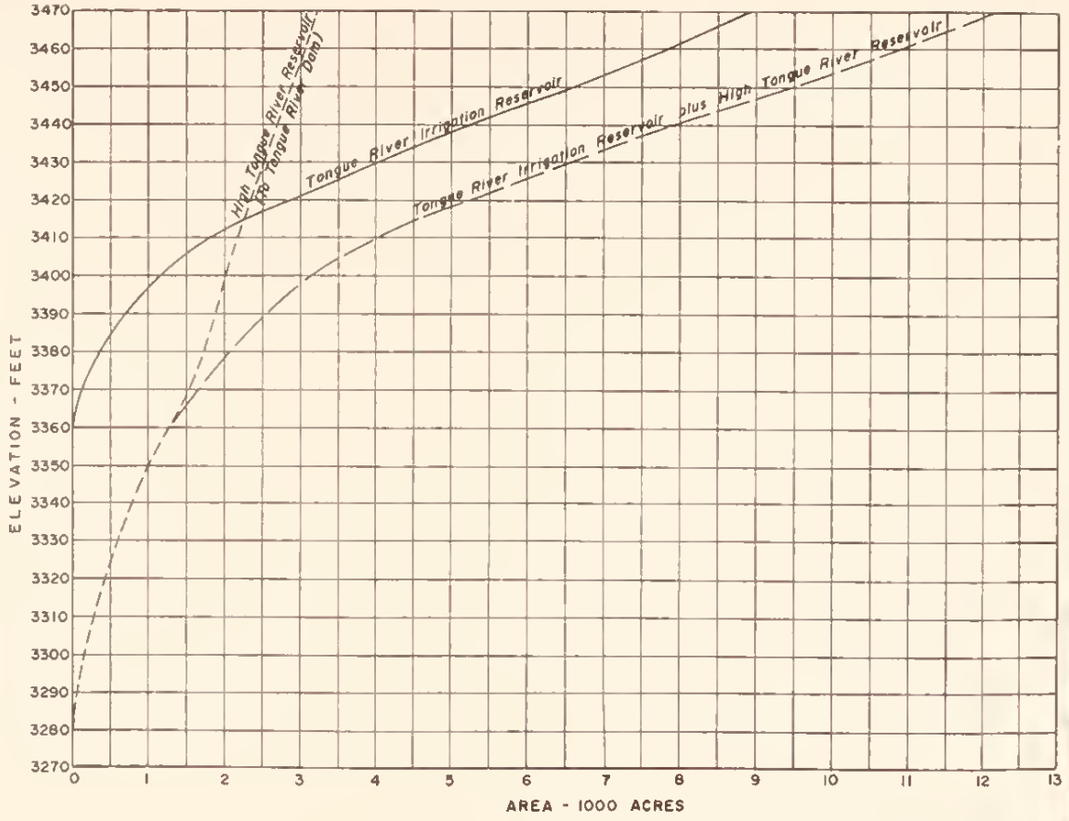
"The yield studies were made for May through September release of the natural inflow up to prior rights of 342 cfs. 342 cfs is .72x475 cfs and reflects rediversion and reuse of return flows as demonstrated by the Use Factor developed in the "Water Allocation Study." The winter release used in the yield studies was the natural inflow up to 75 cfs."

The following is quoted from the Bechtel Basic Design Report:

> "The 1948 U.S.B.R. storage vs. elevation curve was used to develop the present total storage curve shown on Drawing 6694-111-002.
>
> "A siltation and dead storage allowance of 21,000 acre feet has been adopted in addition to the required active storage to provide silt storage through the year 2008 with some 600 acre feet of dead and silt storage remaining at that time.
>
> "It must be recognized that this siltation analysis is based on minimal data. After the increased Tongue River Reservoir has been in operation for some 15 or 20 years a siltation survey should be made as a check on reduction of storage.
>
> "Analysis
>
> "A series of computations to determine the relationship between various storages and yields were made. The area and capacity curves are shown on Drawing No. 6694-111-002. The results of the yield and gross storage (including siltation and dead storage) calculations are shown on Drawing 6694-111-003."

The results of the Bechtel yield studies are summarized on Drawing 6694-111-003, which is presented herein for reference.


Tongue River Irrigation Reservoir
High Tongue River Reservoir (To Tongue River Dam)
Streambed at State line El. 3441.5
Tongue River Irrigation Reservoir plus High Tongue River Reservoir
Spillway Crest El. 3424.4
Minimum Active Storage El. 3310
ELEVATION FEET
VOLUME - 1000 A F


High Tongue River Reservoir (To Tongue River Dam)
Tongue River Irrigation Reservoir
Tongue River Irrigation Reservoir plus High Tongue River Reservoir
ELEVATION - FEET
AREA - 1000 ACRES

J. GEORGE THON 1850E MONTANA PROFESSIONAL ENGINEER

NO	DATE	REVISIONS	BY	CK	PROJ ENGR	MGR SP PROJ	MGR ENGR

WATER SUPPLY STUDIES
RESERVOIR AREA AND CAPACITY

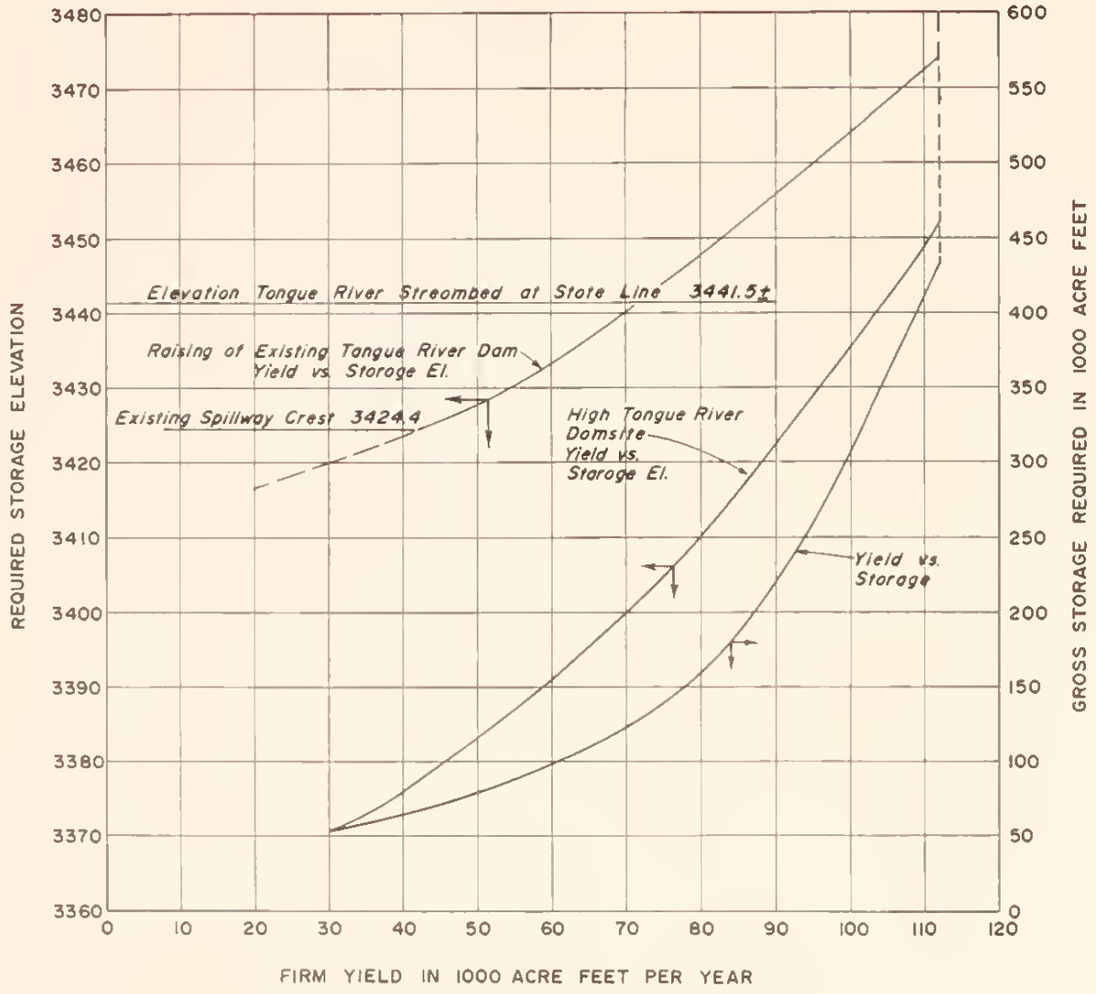
TONGUE RIVER PROJECT
MONTANA WATER RESOURCES BOARD
HELENA, MONTANA

APPROVED _____ DATE _____

BECHTEL CORPORATION
SAN FRANCISCO

DESIGNED	PROJ ENGR	RCH
DRAWN SHIMADA	MGR SP PROJ	RVT
CHECKED RMS	MGR ENGR	

JOB No.	DRAWING No.	REV.
6694	6694 - III - 002	



Firm yield and storage requirements based on Minimum Storable Inflow - Realistic Allocation Study - Downstream Releases 342 cfs Irrigation and 75 cfs winter flow

MONTANA
J. GEORGE THIGPEN
1850 E
PROFESSIONAL ENGINEER

NO.	DATE	APPROVED	BY	CK'D	PROJ. ENG'R	MGR. SP. PROJ.	MGR. ENG'R.

BECHTEL CORPORATION
SAN FRANCISCO

DESIGNED _____ PROJ ENG'R. R.C.H.
DRAWN S.H.D.A.D.R.A. MGR SP PROJ J.G.T.
CHECKED R.A.S. MGR ENG'R _____

WATER SUPPLY STUDIES
YIELD - STORAGE - STORAGE ELEVATION

TONGUE RIVER PROJECT
MONTANA WATER RESOURCES BOARD
HELENA, MONTANA

APPROVED _____ DATE _____

JOB No.	DRAWING No.	REV.
6694	6694 - III - 003	

GEOLOGIC SUMMARY*

"Investigations

"The geological explorations for the Tongue River Project were carried out in two phases. The first phase, conducted during the summer and fall of 1967, explored the general geology of the project area and site geology at the existing Tongue River Dam and two new downstream sites. After determination of project storage requirements and adoption of a plan for development at the Four Mile Creek site, a second phase of specific site geological studies was made for the High Tongue River Dam in the summer of 1968. These second phase studies were made to develop additional specific design data for that dam.

"General Geology

"The Tongue River is one of many rivers that flow north and northeastward from the northwest trending Continental Divide in western Montana and northwestern Wyoming. It originates in Wyoming on the northeast flank of the Big Horn Mountains, a vertically uplifted fault block trending northwestward across the Montana-Wyoming border. After leaving the Big Horn Mountains, the river meanders across the Great Plains Province to its confluence with the Yellowstone River near Miles City, Montana.

"The surface of the Great Plains Province in the vicinity of the Tongue River Project is composed of well stratified sedimentary rocks of continental origin deposited during erosion of the ancestral Rocky Mountains. These sedimentary rocks are part of the Fort Union Formation which is Eocene in age.

"Post-Eocene mountain building resulted in uplift and formation of the Big Horn Mountains. The Tongue River came into being and began eroding its way through the sedimentary rocks until presently it has downcut several hundred feet below the original plain and formed the Tongue River valley.

"The Big Horn Mountain uplift upwarped the western edge of the Fort Union Formation and other sedimentary units, but the deformation did not affect the beds in the vicinity of the Tongue River dam sites. These strata are essentially flat-lying, unfolded, and unfaulted.

* Excerpts from Basic Design Report, Bechtel, Inc.

"Local Geology

"From the Tongue River Dam to Four Mile Creek, the Tongue River has cut into the Fort Union Formation forming a valley from 100 to 350 feet deep and about 1300 feet wide. The strata of the Tongue River Member of the Fort Union Formation are well exposed in steep cliffs along the river and consist primarily of siltstone, sandstone, and an unusual sequence of baked sandstone and shale and some coal beds. Several coal beds in the siltstone unit are traceable for some distance, but thicken and thin along their outcrop.

"The weathered exposures of sandstone are typically light yellow to buff and the siltstone is light gray. Cores of unweathered sandstone are buff to light gray and the siltstone is gray to dark gray.

"The Tongue River Member is a continental deposit and possesses the sedimentary features common to sediments deposited under intermittent, torrential conditions. Features such as variation in thickness within a relatively short horizontal distance, pinching out of strata, cross bedding, and cut-and-fill structures are present at many places along the cliffs. Rock units at the three sites investigated generally showed consistency in thickness and elevation of particular beds but differences were observed.

"Coal Beds and Baked Rock

"The portion of the Tongue River valley studied lies in the northward extension of the Sheridan coal field. The coal is sub-bituminous with several beds being of commercial thickness and quality. These beds crops out along the cliffs of the valley and are easily recognized.

"A unique bedrock feature in and around the Tongue River valley is the presence of prominent, resistant, cliff forming exposures of baked sandstone and shale. These rocks are brick red to salmon color as a result of baking from the burning of underlying coal beds. Sandstone beds have been altered in color and hardness but are still recognizable as sandstone. The siltstone beds have been hardened in some cases to porcellaneous shale and fused to slag. The baked rocks are locally referred to as "clinker" and "scoria," but the majority of the rock is recognizable as sandstone and shale.

"The burned coal left voids that induced collapse of the overlying baked rocks producing collapse breccia.

Cooling of the baked rocks produced contraction joints and horizontal partings along incipient bedding in siltstone which furthered breakdown of the rock. Because of the many fractures and joints the baked rocks are extremely permeable, but yet resistant to erosion because of their hardness.

"The coal fires burned at the outcrops and where overburden was relatively thin, large surface areas were baked, but where overburden was thick, the baking extended less far back into the hill, but still often for several hundred feet. The vagaries of such baking are exhibited by rapid lateral change from baked to unbaked rocks."

"The strata dip south beneath the floor of the valley. The local coal beds with engineering and geologic significance to this study are the Canyon bed,the underlying Wall bed, and several thin local beds between these two main beds. In exposure these beds have been burned and have been replaced by baked rock. However, where burning did not take place, as in the subsurface, the beds are still fresh coal. The Wall bed dips beneath the Tongue River just north of the Four Mile Creek site and is not exposed from there to the existing dam. The thick coal bed encountered in DH-1 at the High Tongue River dam site and DH's 3, 5, 6, 7 and 8 at the Oxbow site, is believed to be the Wall bed. The greatest thickness of this bed, now baked rock, in exposures north of Four Mile Creek is 32 feet, but where penetrated in drill holes at the Oxbow site it is 54 feet of coal and 60 feet of coal beneath High Tongue River Dam Site. To the north of Four Mile Creek the bed thins and eventually becomes several thin beds separated by siltstones.

"Three to four local beds ranging in thickness from one to four feet are present in the vertical interval of 150 feet above the river surface and whether these local beds are continuous from the existing Tongue River Dam to Four Mile Creek is not certain, but beds having approximately the same elevation and thickness are found at the three sites.

"The Canyon bed is baked in exposures which rim the valley and is easily recognized by its brick red color. The bottom of the Canyon bed is generally about elevation 3450 to 3500.

"Natural Gas Seeps

Residents along the river in the vicinity of the dam sites report seeps of natural gas bubbling up

through the river. The bubbling is especially noticeable during low stands of the river when the water is less turbulent and when the river is frozen over. The gas has been trapped in small containers and when ignited burns with a blue flame.

"Five locations were cited where natural gas has been reported in the river:

1. Near the U.S.G.S. stream gaging station below the dam.

2. Near Mr. Lee's house at his ranch.

3. Mr. Thompson's meadow.

4. Near the old water wheels at the Oxbow site.

5. At High Tongue River Dam site - Drill holes 104 and 105."

"IV. GEOLOGIC INVESTIGATION *

"A. Previous Investigations. During exploration for the Tongue River Dam in 1937, more than 20 core holes were drilled in the immediate area of the present dam. The rock units logged in these holes correlate with those units found in the present drill holes and have been used to amplify the subsurface geology. Grouting at the spillway and left abutment was done by others in 1939-40 and 1965. The results of the work done by others downstream of the dam is unknown.

"B. Geologic Mapping. The three dam sites were mapped at a scale of 1" = 100' on a topographic base prepared from aerial photographs taken in June, 1967. Particular attention was given to detailed mapping of local coal beds and baked rock which could permit leakage if present in abutment areas. Geologic mapping of contacts crossing contours more accurately depicted the dip than the plotting of many strike and dip measurements taken on relatively flat or undulating beds. Such measurements could be highly variable and thus misleading and were therefore omitted.

"C. Stragraphic Sections. Seventeen stratigraphic sections were measured in the vicinity of the three dam sites. The purpose of these sections was to:

1. Fill in detailed geology between drill holes.

* Excerpts from Geologic Report of Damsites, Bechtel, Inc.

2. Extend detailed geology beyond drill holes without requiring additional drill holes.

3. Determine the presence and thickness of coal bed.

"Correlation of the stratigraphic sections for each site are shown on Drawings 6694-V-003, -006, and -009. Their locations are indicated by Roman numerals on the geologic maps.

"D. Subsurface Exploration. The subsurface geologic exploration at the three sites was performed during the period of July 10, 1967 to September 28, 1967. Rotary type drill rigs were used in the rock coring and soil sampling. Eighty-three split tube soil samples were obtained from the unconsolidated materials. Continuous coring of 1914 feet of bedrock with a double tube, diamond bit NX core barrel resulted in an average recovery of 93 percent from the 22 holes. Water loss tests were made using a pump with capacity of 20 gpm

"V. ENGINEERING GEOLOGY OF DAM SITES

"A detailed description of the geographic and geologic features and the foundation explorations are given for each site in downstream order.

"A. Tongue River Dam (Existing).

"1. General. The dam is a zoned, earthfill structure completed in 1939 for the Montana Water Conservation Board (present Montana Water Resources Board). It is primarily an irrigation dam and secondarily provides flood control. The dam is approximately 85 feet high, with a crest length of 1650 feet, has a downstream toe elevation of 3375 feet and crest elevation of 3442 feet. The spillway is an uncontrolled chute on the left abutment with a crest elevation of 3424.2 and a crest length of 350 feet. The outlet works is a 16-foot diameter concrete-lined horseshoe tunnel with control provided by a slide gate in line with the dam axis.

"2. Physiography. The dam is located in a sedimentary sequence of siltstone, sandstone, coal beds, and baked sandstone and shale with local occurrences of vesicular "scoria" and natural slag. The sedimentary rocks are part of the Tongue River Member of the Fort Union Formation. The Tongue River in this area is characterized by many hairpin bends resulting in steep cliffs on the outside of the bend

and a gently sloping, sometimes terraced, surface on the inside. The valley bottom is flat and ranges from 600 to more than 1300 feet wide. The sandy-gravelly alluvium in the valley is from 25 to more than 50 feet thick.

"3. Geologic Exploration. The geologic investigation consisted of: (1) review of construction drawings of the existing dam which show drill hole locations and logs; (2) study of 1967 aerial photographs; (3) surface mapping at a scale of 1" = 100', shown on Drawing 6694-V-001; (4) drilling of seven exploratory drill holes, four of which were in the dam proper and were provided with piezometers; and (5) measurement of six stratigraphic sections ranging from 28 to 116 feet. Backhoe pits, excavated as part of the soils exploration, provided an indication of the thickness of terrace deposits at certain locations.

"4. Stratigraphic Sections. The six stratigrahic sections shown on Drawing 6694-V-003 measured in the vicinity of the existing dam cover 221 vertical feet from Elevation 3335 in the spillway bottom to Elevation 3556 at the top of the hill at the right abutment. The sections illustrate the presence of sandstone and coal beds in the predominantly siltstone sequence. Section II depicts the abrupt lateral change from coal to collapsed baked rock and Section I shows the absence of baked rock when compared with Section III which is immediately upstream. Section II correlates with the log of DH-5, particularly the 20-foot thick coal bed.

"The combination of drill hole logs and stratigraphic sections shown on Geologic Section A-A', Drawing 6694-V-002, depicts the presence of a 20-foot thick coal bed at either end of the dam and baked rock on both sides of the spillway. The baked rock probably occupies the vacancy left by the consumed coal and is predominantly the baked equivalent of the sandstone seen above the coal in DH-5. The thin coal bed below the thick coal bed correlates from DH-5 across to Stratigraphic Section II.

"5. Seepage. Seepage has been occurring at the dam since the reservoir reached design elevation. This seepage occurred on the left side of the spillway, under the spillway, and at the first canyon downstream of the right abutment. Seepage control across the alluvial streambed section was provided in 1939-40 by a cutoff trench to bedrock about 80 feet upstream of the dam axis.

"Significant seepage was observed in June, 1967, on the left side on the spillway at the contact of the baked rock with the underlying siltstone (see Stratigraphic Section III). Seepage has been occurring at this point since completion of the dam in 1939. Other seepage noted was along the right side of the river immediately downstream of the dam and a marshy area exists in the first downstream canyon on the right. These also are areas of seepage which have persisted since 1939. It appears that right abutment seepage could be resulting from water travelling through the 20-foot thick coal encountered in DH-5 which would account for the long, wet area found at about elevation 3375 along the right side from the dam downstream for at least 400 feet.

"Water levels have been monitored by piezometers. The water level in DH-5 is about the same as the surface of the reservoir and fluctuates directly. No water level was obtained in DH-6 and DH-7 because of caving.

"6. Left Abutment. The left abutment ridge rises 150 feet above the valley floor and about 100 feet above the existing spillway crest. The log of DH-6 and left abutment backhoe pits 1, 2, and 3 show a cover of terrace deposits ranging in thickness from 5 to greater than 12 feet. The deposits are gravelly sand underlain by interbedded sandstone and siltstone which are in turn underlain by baked rock. The sequence of rock units is shown by the log of DH-6 and Stratigraphic Sections I, II, III and IV.

"7. River Section. Except along the cutoff section, the dam rests on alluvial material as shown on Geologic Sections A-A', B-B', and C-C'. The silty sand and gravel alluvium overlies sandstone bedrock which here is a competent foundation rock.

"8. Right Abutment. In descending order, from the dam crest elevation, the right abutment is composed of interbedded sandstone and siltstone, massive sandstone, massive coal, siltstone and coal, and massive sandstone. The stratigraphy of the right abutment is shown by the log of DH-5, Geologic Section D-D', and Stratigtaphic Sections V and VI.

"Slopewash, exceeding 10 feet in thickness was found in a dozer trench immediately downstream of the dam on the right abutment. If the dam is raised, the downstream fill would lap onto the area of this unconsolidated material.

"SEISMICITY

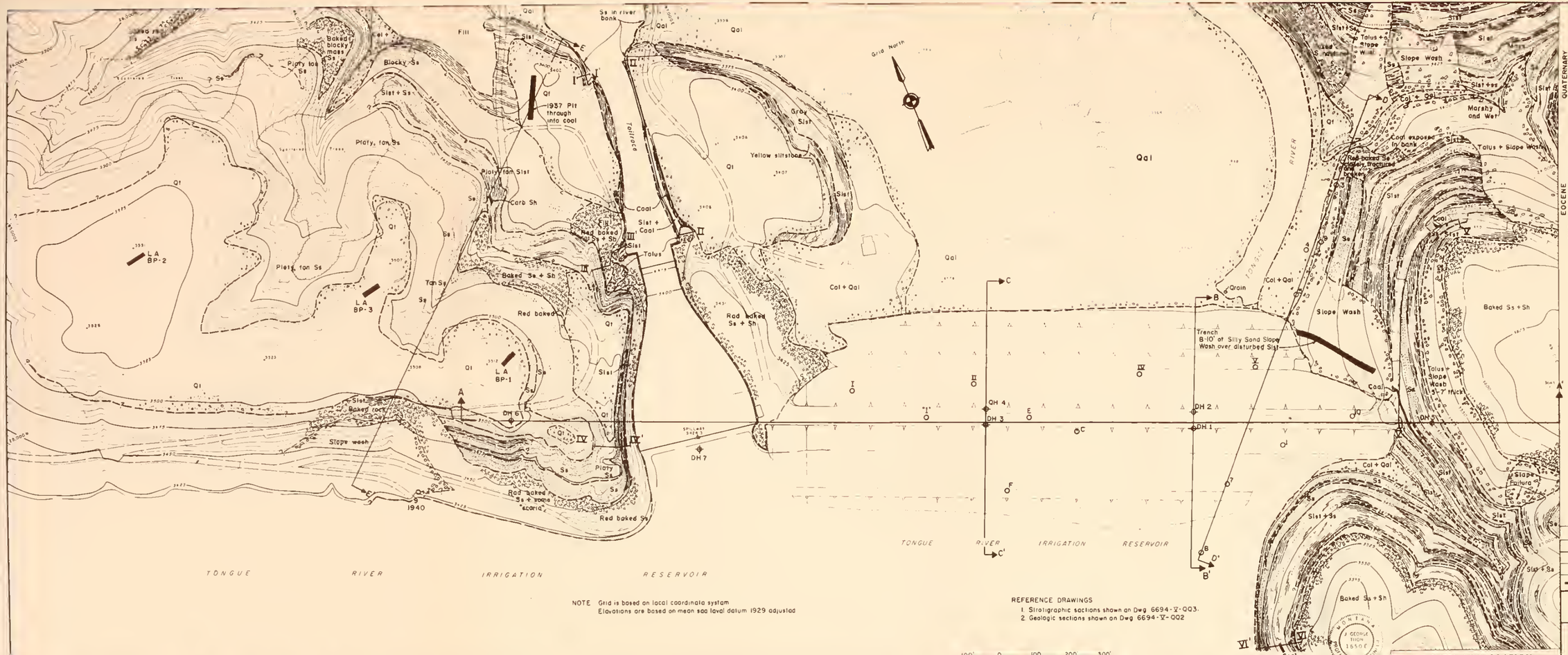
"The area of the Tongue River is not considered to be seismically active. During the period of record from 1852 to 1966, only one earthquake of intensity V or greater has had an epicenter within a 75-mile radius of the dam. This was an intensity V shock in 1925 with its epicenter about 38 miles south of Sheridan, Wyoming.

"The Seismic Regionalization Map, Drawing 6694-V-010, in the supporting data shows the eastern half of Montana to be in a maximum intensity zone of VII which is one of the lower in the country.

"The Seismic Probability Map, Drawing 6694-V-011, in the supporting data shows the site to be in Zone 1 where damage would be minor.

"The closest, most recent major earthquake occurred at Hebgen Lake on August 17, 1959. The shock had a Modified Mercalli intensity of X at the epicenter which was located about 225 miles west of the Tongue River Dam.

"An earthfill dam in the Tongue River area would sustain little damage from an earthquake of intensity VII whose epicenter was in the dam area. The probability of such a quake occurring is statistically low. It is recommended that a horizontal seismic factor of 10% be used for design."



NOTE Grid is based on local coordinate system
Elevations are based on mean sea level datum 1929 adjusted

REFERENCE DRAWINGS
1. Stratigraphic sections shown on Dwg. 6694-Y-003.
2. Geologic sections shown on Dwg 6694-Y-002

100' 0 100 200 300'
SCALE
Contour Interval 5

EXPLANATION

QUATERNARY

- Talus + Slope Wash: Silt, sand, gravel and boulders derived from weathering and breakdown of steep slopes.
- Qal: Alluvium silt, sand and gravel in river bottom and lowlands.
- Col + Qal: Colluvium + Alluvium- locally derived slope wash merging with alluvium.
- Qt: River terrace deposits: silt sand and gravels, characterized by well rounded predominantly sedimentary gravel and distinctive igneous gravel.

EOCENE
FORT UNION FORMATION
Tongue River Member

- Baked Ss + Sh: Locally referred to as "clinker" and "scoria"; red baked sandstone and shale., platy to closely broken and jointed, some vesicular "scoria" has distinctive red brick color; extremely permeable
- Slst: Siltstone- gray laminated to massive' commonly closely broken and jointed, yellow staining and occasional gypsum filling in joints; some clayey beds; ravels when weathered contains coal beds and some carbonaceous siltstone beds.
- Coal: Block crumbly; includes earthy coal beds; coal beds range from 4'0" to >4' in thickness
- Ss: Sandstone' Buff to gray very fine-to medium-grained with some coarse grained sequences, weakly to moderately well cemented strata; massive to thinly bedded with occasional cross bedded sequences relatively free of joints and fractures; contains little to no coal

SYMBOLS

- A A' Line of Geologic Section.
- V V' Line of Measured Stratigraphic Section
- Spring and/or seepage
- Prominant sandstone ledge
- DH-1 1967 Drill Hole
- O Drill Hole by others prior to investigation.
- BP-1 Backhoe Pit and/or Trench.
- ?..... Geologic contact, dashed where inferred, guarded where doubtful, dotted where obscured.

TOPOGRAPHIC MAP
BY
R M TOWILL, CORP
DATE OF PHOTOGRAPHY JUNE 20, 1967
Geology mapped July, 1967

NO.	DATE	REVISIONS	BY	CK'D	APP'D

TONGUE RIVER DAM GEOLOGIC MAP

TONGUE RIVER PROJECT
MONTANA WATER RESOURCES BOARD
HELENA, MONTANA

BECHTEL CORPORATION
SAN FRANCISCO

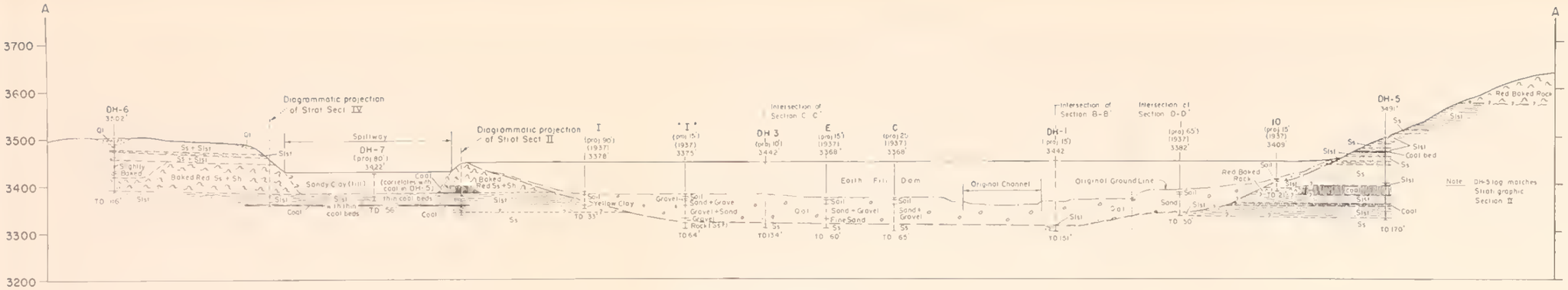
DESIGNED		PROJ ENGR.	
DRAWN	EAS	MGR OF PROJ.	
CHECKED		MGR ENGR.	

APPROVED _____ DATE _____

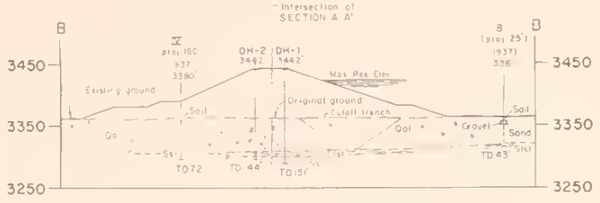
JOB NO.	DRAWING NO.	REV.
6694	6694-Y-001	

GRAPHIC SYMBOLS

- Talus + Slope Wash
- Qal
- Col + Qol
- Qt
- Baked Ss + Sh
- Slst
- Coal
- Ss



GEOLOGIC SECTION A-A'



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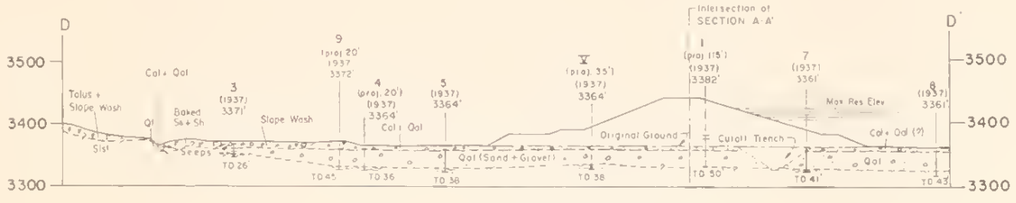

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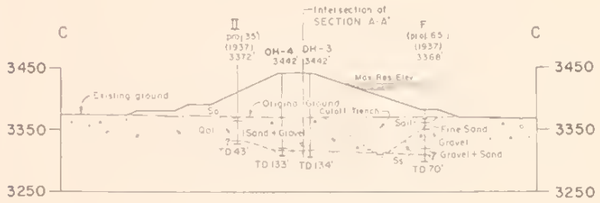

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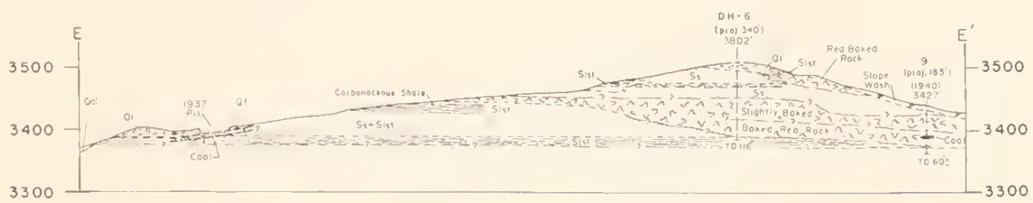


GEOLOGIC SECTION E-E'

REFERENCE DRAWINGS

1. All 1937 drill holes are pre-construction holes. See Montana State Dwg 2-D, PWA No 1054-D, July 1937
2. For location of geologic sections see Dwg no 6694-V-001

100 0 100 200 300 400

SCALE

BECHTEL CORPORATION
SAN FRANCISCO

DESIGNED
DRAWN
CHECKED
PROJ ENGR
MGR SP PROJ
MGR ENG'R

TONGUE RIVER DAM
GEOLOGIC SECTIONS

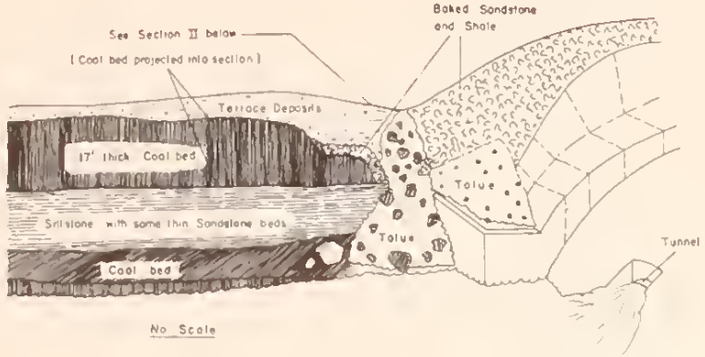
TONGUE RIVER PROJECT
MONTANA WATER RESOURCES BOARD
HELENA, MONTANA

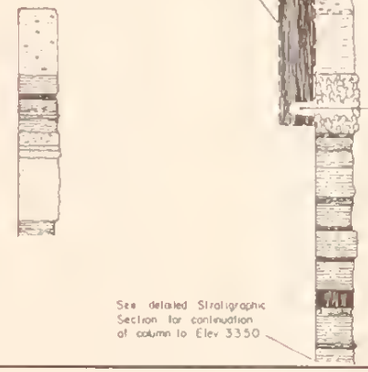
APPROVED DATE

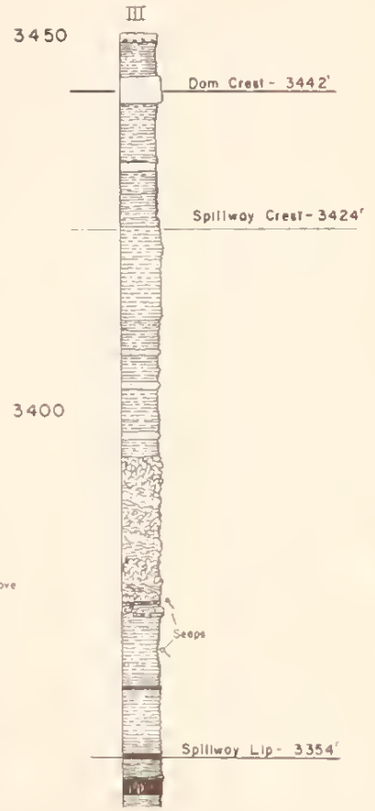
JOB NO. 6694

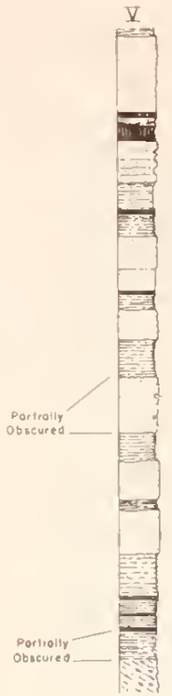
DRAWING NO. 6694-V-002

REV



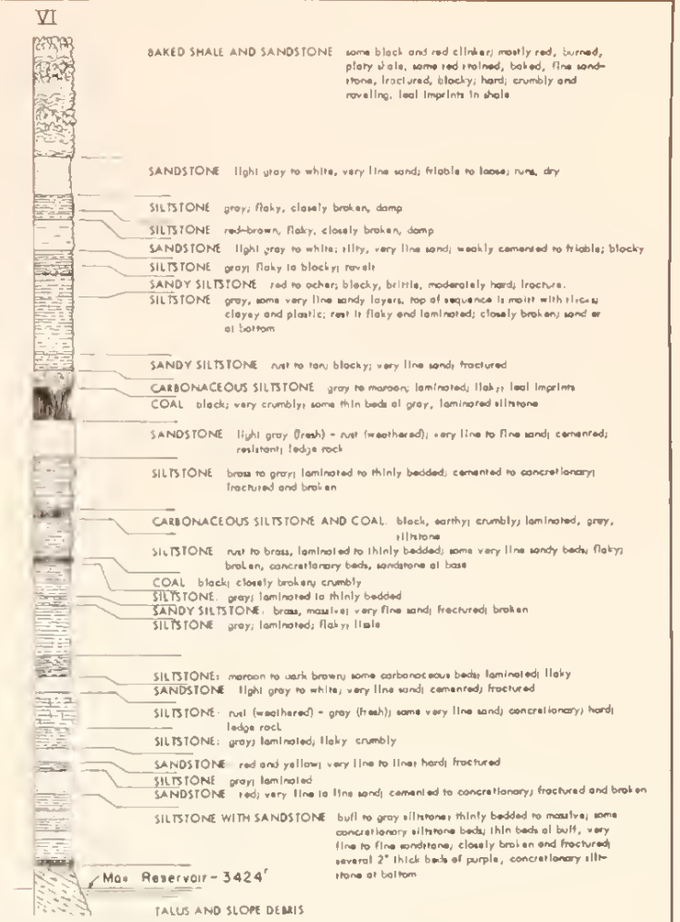






GRAPHIC SYMBOLS FOR STRATIGRAPHIC SECTIONS

- Slope Wash
- Terrace
- Baked Sandstone and Shale
- Siltstone
- Concretionary Siltstone
- Carbonaceous Siltstone
- Coal
- Sandy Siltstone
- Silty Sandstone
- Sandstone
- Concretionary Sandstone


VI
BAKED SHALE AND SANDSTONE some black and red clinker; mostly red, burned, platy shale, some red stained, baked, fine sandstone, fractured, blocky; hard; crumbly and raveling. leaf imprints in shale
SANDSTONE light gray to white, very fine sand; friable to loose; runs, dry
SILTSTONE gray; flaky, closely broken, damp
SILTSTONE red-brown, flaky, closely broken, damp
SANDSTONE light gray to white; silty, very fine sand; weakly cemented to friable; blocky
SILTSTONE gray; flaky to blocky; ravelt
SANDY SILTSTONE red to ocher; blocky, brittle, moderately hard; fracture.
SILTSTONE gray, some very fine sandy layers, top of sequence is moist with traces clayey and plastic; rest is flaky and laminated; closely broken; sand at bottom
SANDY SILTSTONE rust to tan; blocky; very fine sand; fractured
CARBONACEOUS SILTSTONE gray to maroon; laminated; flaky; leaf imprints
COAL black; very crumbly; some thin beds of gray, laminated siltstone
SANDSTONE light gray (fresh) - rust (weathered); very fine to fine sand; cemented; resistant; ledge rock
SILTSTONE brass to gray; laminated to thinly bedded; cemented to concretionary; fractured and broken
CARBONACEOUS SILTSTONE AND COAL black, earthy; crumbly; laminated, gray, siltstone
SILTSTONE rust to brass, laminated to thinly bedded; some very fine sandy beds; flaky; broken, concretionary beds, sandstone at base
COAL black; closely broken; crumbly
SILTSTONE gray; laminated to thinly bedded
SANDY SILTSTONE brass, massive; very fine sand; fractured; broken
SILTSTONE gray; laminated; flaky; friable
SILTSTONE maroon to dark brown; some carbonaceous beds; laminated; flaky
SANDSTONE light gray to white; very fine sand; cemented; fractured
SILTSTONE rust (weathered) - gray (fresh); some very fine sand; concretionary; hard; ledge rock
SILTSTONE gray; laminated; flaky; crumbly
SANDSTONE red and yellow; very fine to finer; hard; fractured
SILTSTONE gray; laminated
SANDSTONE red; very fine to fine sand; cemented to concretionary; fractured and broken
SILTSTONE WITH SANDSTONE buff to gray siltstone; thinly bedded to massive; some concretionary siltstone beds; thin beds of buff, very fine to fine sandstone, closely broken and fractured; several 2" thick beds of purple, concretionary siltstone at bottom
Max Reservoir - 3424'
TALUS AND SLOPE DEBRIS

REFERENCE DRAWING
1 For locations of stratigraphic sections see Dwg 6694-V-001

NO	DATE	REVISIONS	BY	CK	PROJ ENGR	MGR SP PROJ	MGR ENGR

MEASURED STRATIGRAPHIC SECTIONS AT THE TONGUE RIVER SITE

TONGUE RIVER PROJECT
MONTANA WATER RESOURCES BOARD
HELENA, MONTANA

APPROVED _____ DATE _____

BECHTEL CORPORATION
SAN FRANCISCO

DESIGNED _____ PROJ ENGR _____
DRAWN _____ MGR SP PROJ _____
CHECKED _____ MGR ENGR _____

JOB No.	DRAWING No.	REV
6694	6694-V-003	

CONSTRUCTION MATERIALS*

"Borrow Area Explorations

"The borrow area investigation was conducted between July 10, 1967 and September 16, 1967. The investigation consisted of excavating pits with a backhoe to depths up to 13 feet or until water conditions or bedrock made digging impractical. The average pit depth was approximately 11 feet and the sides of the pits were logged and sampled. Bags of soil representing the different classifications were taken from the sides of the pits and the pits backfilled. The borrow investigation was conducted for two locations; the existing Tongue River Dam and the Four Mile Damsite. Detailed descriptions of these explorations are described for each site in the following sections.

"Tongue River Dam

"Explorations for borrow materials were conducted in the valley along Leaf Rock Creek, on the Left Abutment and in Borrow Areas A, B, C and E. Photocontour maps of these borrow areas as well as the logs and soil test data are presented in the Supporting Data.

"The Leaf Rock Creek borrow area is approximately 8000 feet long by 600 feet wide and composed of an alluvial filled valley overlain by fine-grained material. A total of 8 backhoe pits were dug in this area, and the logs are shown on Drawing No. 6694-VI-009. The fine-grained materials are clays and silts mixed with fine-grained sands usually being of low plasticity and with layers of clean sands and gravels scattered throughout. Generally this finer material appears to be at least 12 to 13 feet deep in the lower portion of the valley. In the upper 2000 feet of the valley, the fine-grained material decreases in thickness to only about a foot.

"The left abutment and Borrow Areas A and B contain gravelly materials. The logs of pits from these areas are shown on Drawing No. 6694-VI-010. At the left abutment there are 8 to 10 feet of gravel above the bedrock but the area is small and represents only a small quantity. Borrow Areas A and B are relatively small and the water table is near the surface. The area consists of sandy gravel of unknown depth covered with 3 to 7 feet of silts and silty sands. Because the gravel would have to be removed from below the

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* Excerpts from Basic Design Report, Bechtel, Inc.

water table and the apparent small quantity, these areas were not considered to be of great importance other than perhaps for filter or aggregate production.

"Borrow Area C is a generally level field adjacent to the river. Three pits in this area indicate silty and clayey sandy gravels overlain in some parts by 4 to 5 feet of silty clay (logs are shown on Drawing No. 6694-VI-011.). The clayey material is of small quantity. Gravelly material would require processing to be used as filter, drain or aggregate material.

"Borrow Area E is divided into a lower flat portion and a terraced portion. Four pits in the flat portion indicated 8 to 11 feet of clayey, silty, sandy soil averaging approximately 9 feet in depth. (See logs on Drawing No. 6694-VI-011). Pits in the terraces indicated sandy gravel with some fines.

"CONCRETE AGGREGATES

"The most feasible local source of concrete aggregates would be located on the upper terraces. While these areas were not specifically investigated for concrete aggregates the grain size distribution curves are available from the borrow area explorations. It is not known at this time as to whether these upper terrace deposits would meet acceptable concrete aggregate tests. The gravel deposits lying along the present streambed contain an appreciable amount of sedimentary and softer rocks and are therefore less likely to be acceptable.

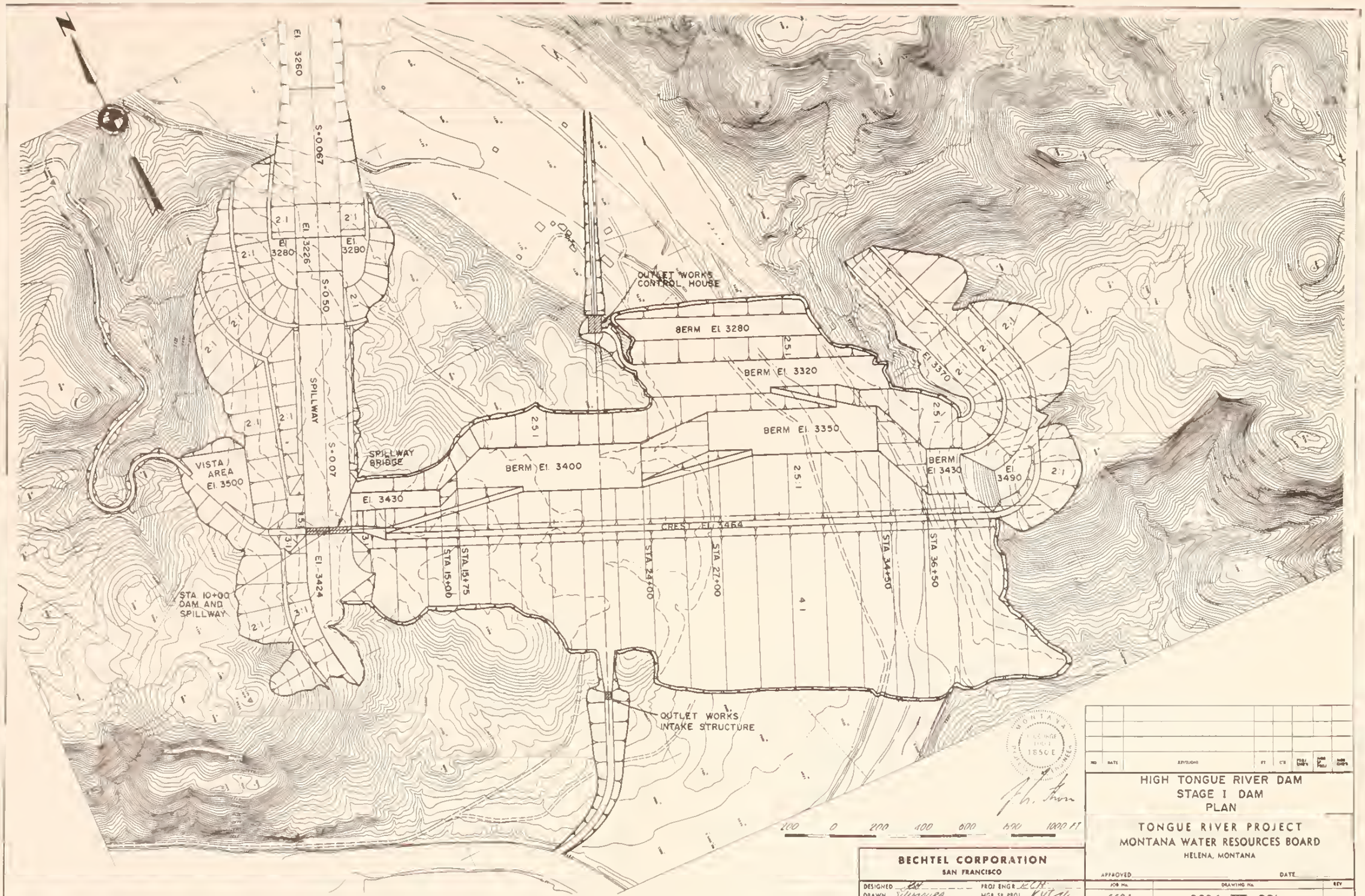
"The nearest known commercial sources of concrete aggregates are located at Sheridan, Wyoming, where three firms are producing acceptable materials. The aggregate deposits are all located on the upper terraces west of town and are from a similar geologic period to those found along the Tongue River.

"The concrete aggregate used in the present dam came from a pit located a few miles upstream of the dam. Nothing is known regarding the aggregate plant, the resulting product or the type of cement used."

"RIPRAP

"No known sources of good, hard, sound rock are located along the Tongue River. A fairly firm cemented sandstone rib was visually examined and rejected for being too soft for long life. A small possibly useful sandstone layer is present near the High Tongue River damsite as described in the Geological Summary. Baked sandstone and shale, locally known as clinker, while frequently used for road surfacing would produce very little material larger than six inch size. Nearest possible source of an igneous rock that might be suitable for riprap is located in the Big Horn Mountains approximately 40 miles to the southwest. The lack of good riprap was recognized during the construction of the existing dam and thickness was increased from 30 inches to 15 feet measured normal to the slope with the material being the above-mentioned baked shale. The present condition of the upstream face appears to be satisfactory.

"Exposures of baked shale occur at or slightly above the present reservoir while at the Four Mile Dam Site the baked shales are located along the tops of higher ridges generally above any proposed dam."



NO	DATE	REVISIONS	BY	CHK	PROJ ENGR	MGR ENGR

HIGH TONGUE RIVER DAM
STAGE I DAM
PLAN

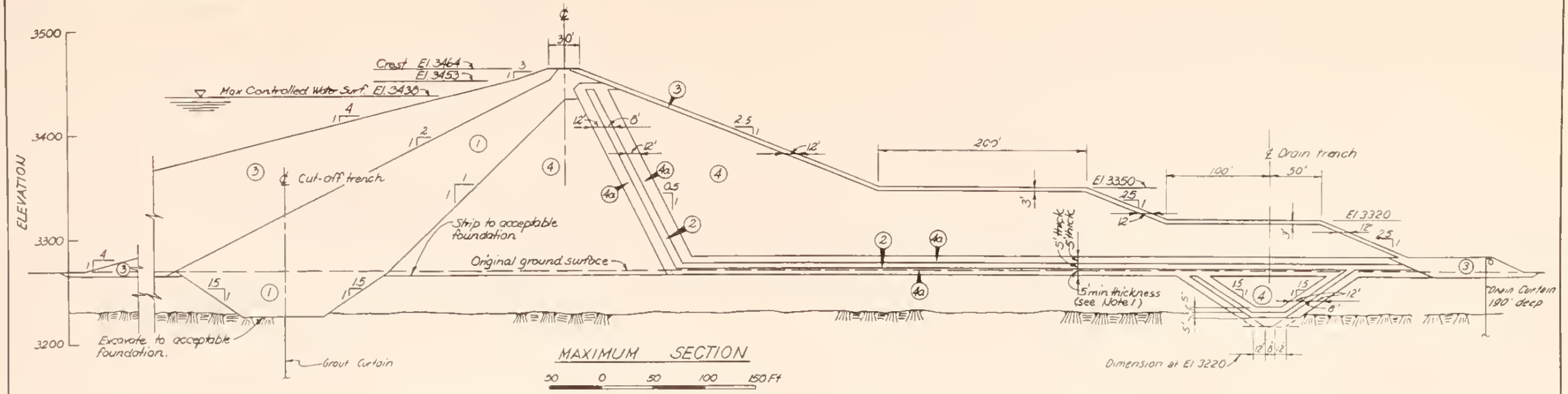
TONGUE RIVER PROJECT
MONTANA WATER RESOURCES BOARD
HELENA, MONTANA

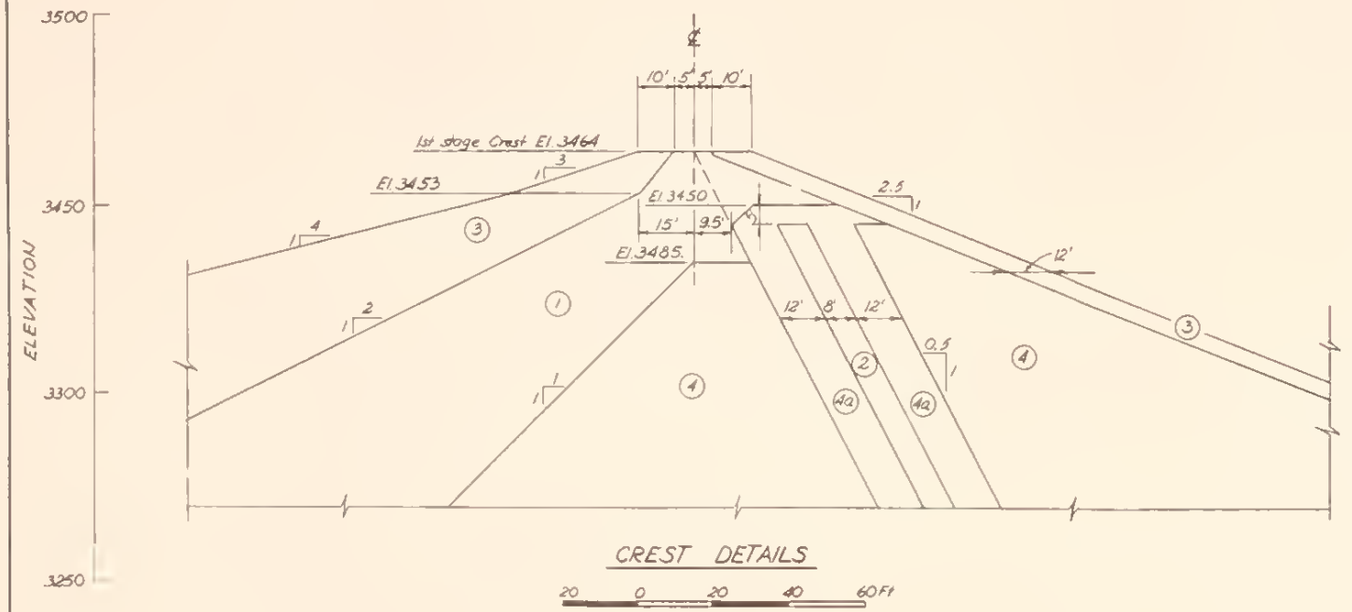
APPROVED _____ DATE _____

JOB No.	DRAWING No.	REV
6694	6694 - VII - 001	

BECHTEL CORPORATION
SAN FRANCISCO

DESIGNED _____ PROJ ENGR _____
DRAWN _____ MGR SP PROJ _____
CHECKED _____ MGR ENGR _____





NOTES:

1. The lower layer of Zone 4a, shall have a thickness of 5 feet where the stripped foundation elevation is 3270 or higher. The thickness shall be increased where the stripped foundation is lower than El 3270 to provide a top of layer elevation of 3275

ZONE	MATERIAL
1	Impervious - from Borrow Areas R, M, L, K, G & I
2	Processed Sand and Gravel
3	"Clinker" or "Baked Rock"
4	Random - Required Excavation or from Borrow Areas R, N, H, G and Post Creek
4a	Select Gravelly Fill from Terrace Borrow Area

NO.	DATE	REVISIONS	BY	CK'D	PROJ. ENGR.	MGR. SP. PROJ.	MGR. ENGR.

HIGH TONGUE RIVER DAM
STAGE I DAM
MAXIMUM SECTION

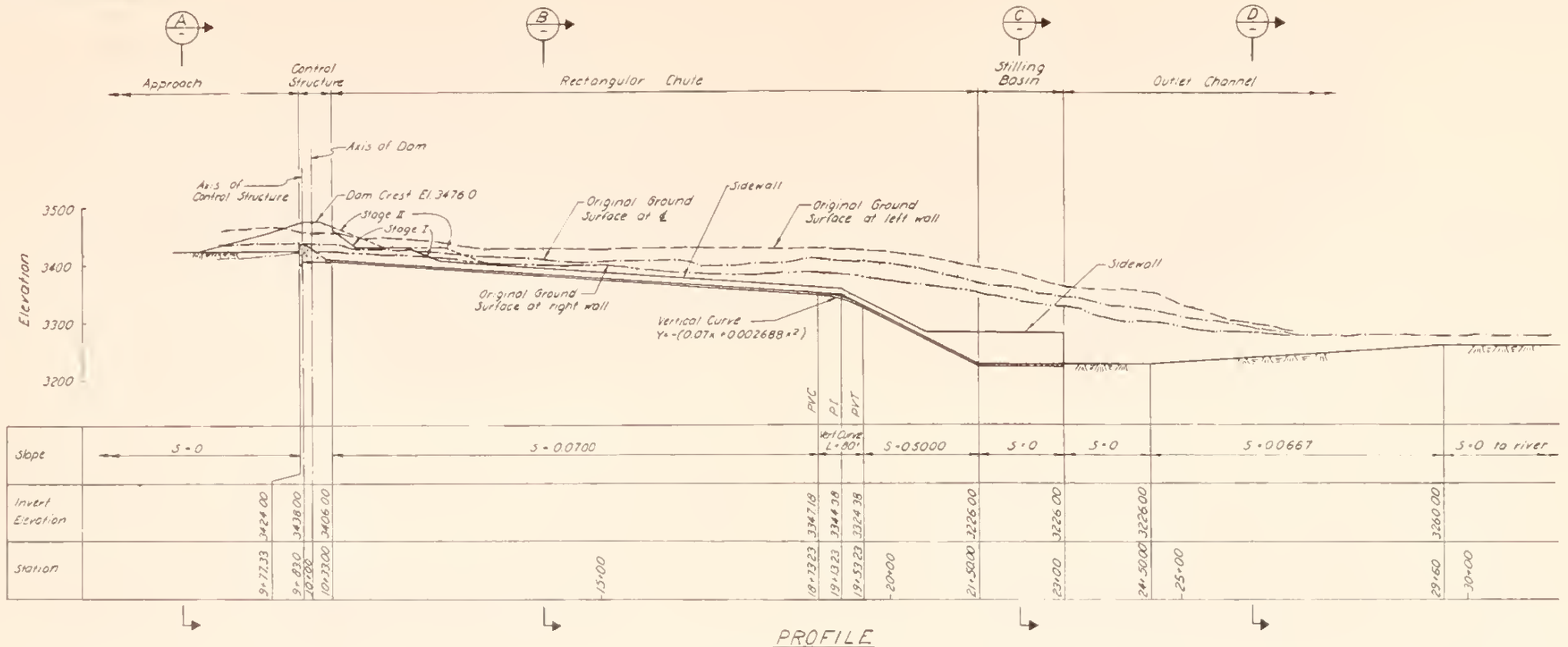
TONGUE RIVER PROJECT
MONTANA WATER RESOURCES BOARD
HELENA, MONTANA

BECHTEL CORPORATION
SAN FRANCISCO

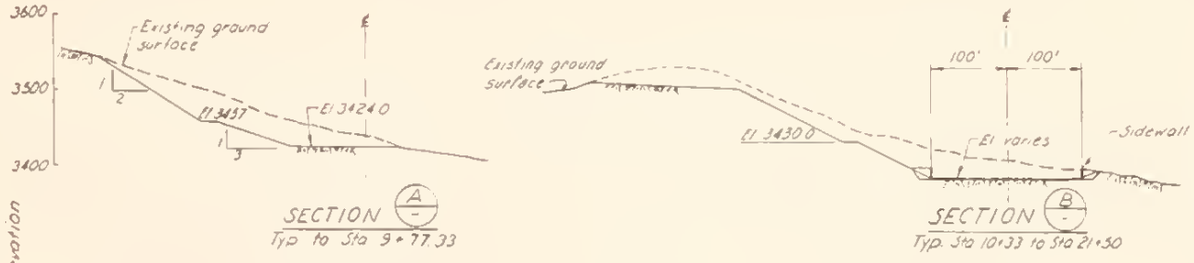
DESIGNED	P.E.U.	PROJ. ENGR.	R.C.H.
DRAWN	J.B.M.	MGR. SP. PROJ.	K.V.T.
CHECKED	P.E.U.	MGR. ENGR.	

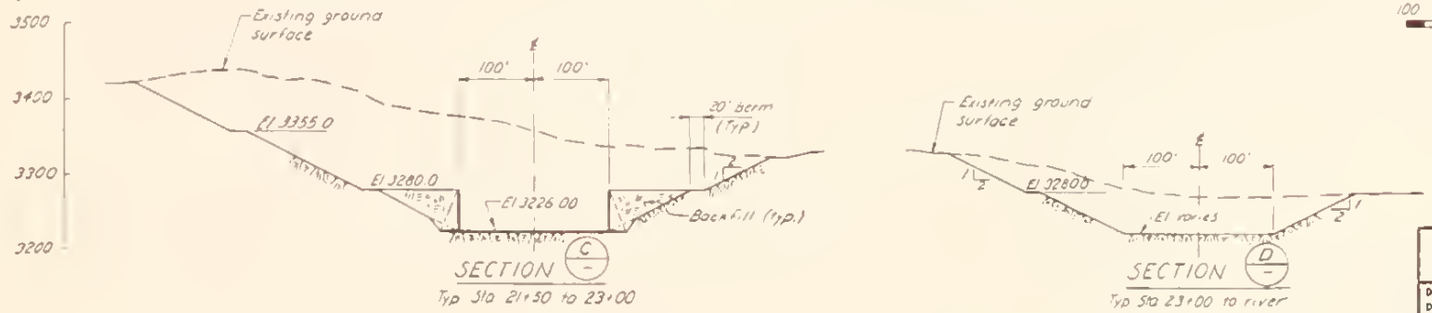
APPROVED _____ DATE _____

JOB No.	DRAWING No.	REV.
6694	6694 - VII - 002	



PROFILE





REFERENCE DRAWING

6694-VIII-001 Spillway Plan

100 0 100 200 300 Ft.

MONTANA J. GEORGE 1850E REGISTERED ENGINEER

NO.	DATE	REVISIONS	BY	CK	PROJ. ENGR.	MGR. SP. PROJ.	MGR. ENGR.

HIGH TONGUE RIVER DAM
SPILLWAY
PROFILE AND SECTIONS

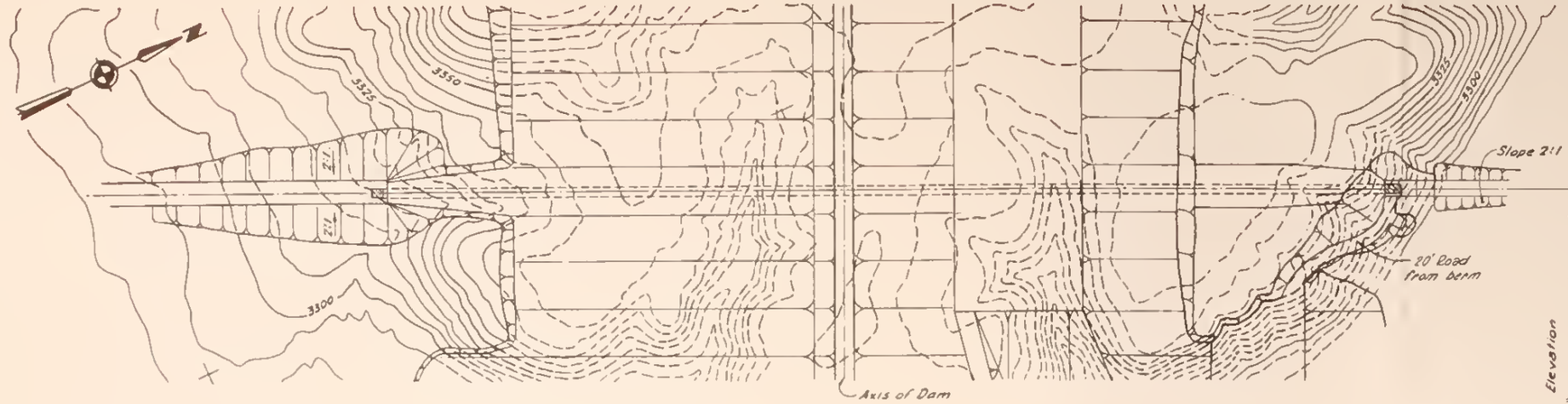
TONGUE RIVER PROJECT
MONTANA WATER RESOURCES BOARD
HELENA, MONTANA

APPROVED _____ DATE _____

BECHTEL CORPORATION
SAN FRANCISCO

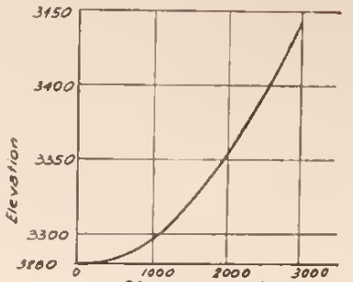
DESIGNED _____ PROJ ENGR. _____
DRAWN M. Mitchell MGR SP PROJ
CHECKED _____ MGR ENGR. _____

JOB No.	DRAWING No.	REV
6694	6694-VIII-002	

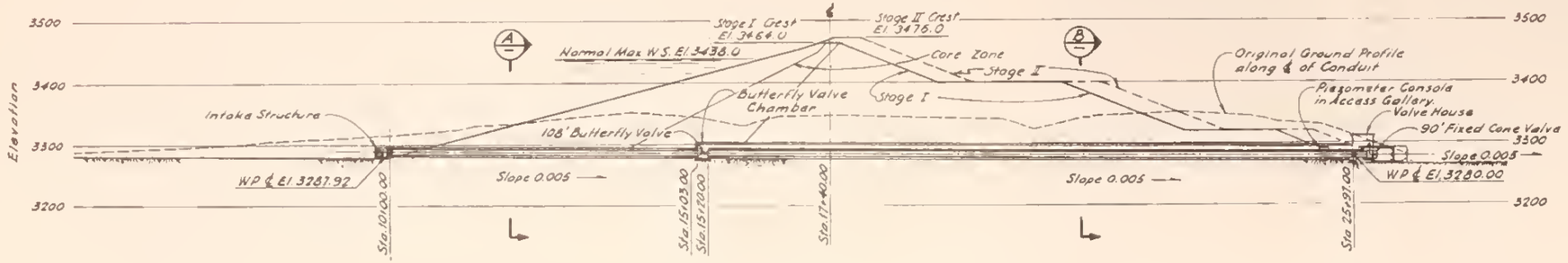


PLAN

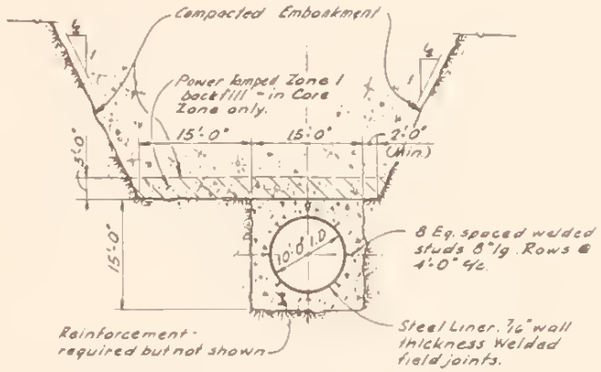
100 0 100 200 300 Feet



RATING CURVE

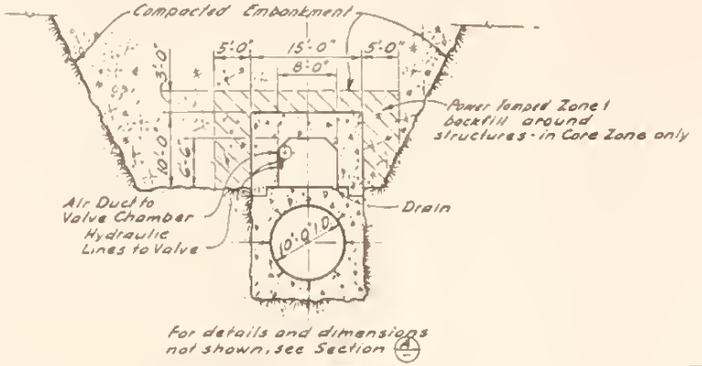


PROFILE ALONG ℄ OF CONDUIT


Compacted Embankment
Power tamped Zone I backfill - in Core Zone only.
15'-0"
15'-0"
2'-0" (Min)
5'-0"
15'-0"
8 Eq. spaced welded studs 8" lg. Rows @ 4'-0" c/c.
10'-0" I.D.
Reinforcement - required but not shown
Steel Liner, 7/16" wall thickness Welded field joints.

SECTION A

Typical - Sta. 10+00 to Sta 15+03.



For details and dimensions not shown, see Section A

SECTION B

Typical - Sta. 15+17 to Sta. 25+97

10 0 10 20 30 Feet

GEORGE THON 1850 E REGISTERED PROFESSIONAL ENGINEER

BECHTEL CORPORATION SAN FRANCISCO			
DESIGNED		PROJ ENGR.	
DRAWN		MGR SF PROJ	
CHECKED		MGR ENGR.	

HIGH TONGUE RIVER DAM
OUTLET WORKS
PLAN PROFILE AND SECTIONS

TONGUE RIVER PROJECT
MONTANA WATER RESOURCES BOARD
HELENA, MONTANA

APPROVED. DATE

JOB No.	DRAWING No.	REV.
6694	6694 - IX - 001	

LIST OF REFERENCES

The following is a list of basic data references utilized in making these studies:

Basic Design Report - Tongue River Project, Bechtel, Inc. 1969

Water Allocation Study - Tongue River Project, Bechtel, 1968

Supporting Data - Water Allocation Study - Tongue River Project, Bechtel, Inc. 1968

Dam Safety Inspection Report - Tongue River Project No. 29, Engineering Bureau, Water Resources Division, Montana Department of Natural Resources.

Summary of the Outlet Tunnel Repairs at Tongue River Dam - Fall 1975, Engineering Bureau, Water Resources Division, Montana Department of Natural Resources.

Supporting Data - Basic Design Report - Tongue River Project, Bechtel, Inc. 1969 which includes the following reports:

Geologic Report - Tongue River Project
Results of Rock Laboratory Testing on Coal Samples
Bechtel, Inc.

Geologic Report of Damsites, Bechtel, Inc.
December 1967

Construction Materials - Gradation Data by Northern Testing Laboratories

Construction Materials - Report of Soil Tests by Geo-Testing, Inc. January 1968

Existing Tongue River Dam
History and Construction Drawings dated 1937 through 1942

Photographs - Construction 1938 and Post-Construction 1939

Geologic Report on Leakage at the Tongue River Dam by Eugene S. Perry, June 20, 1939

Tongue River Dam 1937 and 1940 - Grouting - Final Weekly Report by O. E. Moberg and grout logs

Tongue River Dam - Report and Grouting Logs by Halliburtun Pressure Grouting Service 1965